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NPG Report No. 1452

PLATE PENETRATION TESTS OF SPECIAL TEST MODEL 500 LB. LOW DRAG G. P. BOMB BODIES

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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

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Date 12 APRIL 1956

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U. S. Naval Proving Ground
Dahlgren, Virginia

Plate Penetration Tests of Special Test Model 500 Lb. Low Drag G. P. Bomb Bodies

by

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and
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Terminal Ballistics Department

NPG REPORT NO. 1452

Task Assignment No.
NPG-W4-3c-321-1-56

12 April 1956

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ABSTRACT

The Navy low drag family of general purpose bombs are currently fabricated from high strength steel tubing, with additional improvement in the ballistic properties supplied by a heat treatment. Lyon Incorporated of Detroit, Michigan has developed a process whereby these bomb shapes can be cold formed from commercial steel plate. Inasmuch as this method gave prospect of considerable savings in cost, the Bureau of Ordnance authorized the ballistic testing of a number of the Lyon produced 500 lb. bombs in comparison with standard bombs. The 500 lb. GP Mk 82 bomb produced by the National Tube Division of U. S. Steel was chosen as representative of current production practice. Inasmuch as Lyon Incorporated was not equipped at the time to weld in the inserts for the lifting lugs and fuze charging system, these items were also omitted from the National Tube bombs to permit a more accurate comparison.

The following information was obtained on the two types of bombs by firing them from a 12" railroad gun at 1000 ft/sec against STS armor plate and recovering them in sand behind the targets:

a. Lyon Incorporated bombs made from cold formed, commercial steel plate are inferior in ballistic properties to National Tube Division bombs fabricated from high manganese steel tubing by conventional methods.

b. The Lyon bombs have a plate limit of less than 3/4" thickness of STS plate at 20° obliquity and the National Tube bombs have a penetration limit of 1" STS at 20° obliquity.

c. The Lyon bombs as submitted, fabricated from commercial steel plate, will break up in penetrating 3/4" or heavier STS targets whereas National Tube bombs will remain essentially intact in penetrating targets as heavy as 1" STS at 20° obliquity.

Metallurgical tests in the Naval Proving Ground laboratories indicated that the failure of the Lyon bomb was caused by lack of ductility and toughness, particularly in the nose section of the bomb.

Improvement in the Lyon Incorporated bombs can probably be effected by changing to a steel which will permit heat treatment. Higher impact strength is believed necessary for the material to enable the bombs to withstand the high deceleration forces encountered on plate impacts.

FOREWORD

This is the 97th partial report on Task Assignment NPG-W4-3c-321-1-56 "Bombs and Associated Components" and the final report on Plate Penetration Tests of Special Test Model 500 lb. Low Drag GP Bomb Bodies.

The tests reported were conducted during the period of 22 December 1955 through 9 January 1956 as authorized by reference (a).

The tests upon which this report is based were conducted by G. J. Miskho, LTJG, USNR-R, Firing Officer and Mr. W. H. Hall, Metallurgist, of the Terminal Ballistics Department.

This report was reviewed by:

H. E. ROMINE, Head, Metallurgy Division
Terminal Ballistics Department
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INTRODUCTION

Lyon Incorporated of Detroit, Michigan has developed under the sponsorship of the Bureau of Ordnance a method of cold forming 500 lb. Low Drag GP Bomb bodies from commercial steel plate. The purpose of this development is to determine if a suitable bomb body can be fabricated that will use non-strategic low carbon steel, eliminate as much welding as possible, and show a considerable cost saving over the currently manufactured bomb body.

The armor plate penetration tests described in this report were conducted to:

a. Obtain a direct comparison of the performance of the bomb bodies cold formed from commercial steel plate by Lyon, Incorporated with those fabricated by conventional methods from high manganese steel tubing.

b. Find the maximum plate thickness which each type of bomb body will penetrate and remain in an effective bursting condition.

c. Determine the degree of deformation of each type of bomb body resulting from impact.

A complete metallurgical investigation was conducted on each type of bomb body to obtain a comparison of physical properties, chemical analysis, hardness, Charpy V notch values, macrostructure and microstructure.

DESCRIPTION OF MATERIAL

The Lyon bomb, shown as Figure 1, Appendix B, is similar to the 500 lb. GP Mk 82 Navy bomb. It is 10∀75 diameter, 60-1/2" long, and has a wall thickness tapering from 1-1/4" at the nose to 0∀470 at the base of the ogive. No suspension lugs, fuze charging inserts or fuze charging tubes were included in the four bombs submitted since the contractor was not equipped for such an installation at the time. Five similar bomb bodies, fabricated from tubing, were obtained from the National Tube Division of the U. S. Steel Corporation for the comparison tests, Figure 2. The lugs, inserts and fuze charging conduits were again omitted.

The Lyon bombs were made by cold extrusion or drawing in a 5000 ton Lake Erie hydraulic press using AISI-C1030 steel, starting with a flat blank sheared from 1-3/4" thick annealed plate. Their cold forming process is roughly as follows:

a. Blank 32" in diameter x 1-3/4" thick.

b. Cupped in press to 16" height x 16" outside diameter.

c. Anneal at 1250°F for 30 minutes and air cool.

d. First draw to 20-1/2" height.

e. Anneal as above.

f. Second draw to 28-1/2" height x 15" O.D.

g. Anneal as above.

h. Third draw to 42" x 12" O.D.

i. Fourth draw to 56" forming nose upset on outside.

j. Redraw, forming nose with taper on inside and forming base.

k. Nose formed.

l. Base or tail tapered and formed.

This process is illustrated in Figure 10, Appendix E, which shows sectioned specimens of a 1/3 size prototype bomb. The first specimen on the left is half of the flat disc blank. Some of the steps performed on the 1/3 size bomb, including the first cupping (second specimen shown), have been eliminated in producing the 500 pound bomb.

One unfired bomb of each type was sectioned for the metallurgical investigation. The remaining bombs were inert loaded with a Perlite-cement-water mixture to a 1.55 density and the filler allowed to harden for a minimum of seven days before firing. All the gun-fired bombs had aluminum pressure plates attached to the base, and were of a design which would readily strip off upon target impact without damaging the bomb. A forward bourrelet of 4" width paper tape was

wrapped around the bomb 26"7 aft of the face. The base plate and bourrelet were used to bring the bomb up to the diameter of the gun bore. The noses of the bombs were fitted with the standard, cone shaped, steel nose plug.

DESCRIPTION OF TEST EQUIPMENT

The following equipment and material were used in conducting the firing program:

a. Gun: 12"/35 Army Gun Model 1895. Railway Mount #19

b. Propellant: 30 or 31 lbs. SPDN 4330 powder

c. Targets: 3/4", 1" and 1-1/8" STS armor plate

PROCEDURE

The bombs were inert loaded and after a minimum time of seven days required for hardening and strengthening of the filler, prepared for firing by the addition of the paper bourrelets and base plates. They were fired from a 12"/35 railroad gun, over a 60 foot range, against armor plate targets secured in a butt and backed by a large pile of sand. After each round was fired it was removed from the sand, photographed and examined. Velocities and pressures were measured in the conventional manner by copper gauges and counter chronographs.

RESULTS AND DISCUSSION

Table I, Appendix A, gives the test conditions and results for the three Lyon Incorporated and three National Tube bombs fired during this program. Appendix C contains photographs of all the recovered bombs and illustrates the failures experienced. Appendix D consists of detailed data sheets for each round fired.

Firing Tests

A total of six bombs were fired, three manufactured by Lyon Incorporated and three by the National Tube Division. All of the Lyon bombs penetrated the 1-1/8", 1" and 3/4" STS targets but in each case they broke up badly. The National Tube bombs penetrated the 1-1/8" and 1" targets (two fired against 1" plate) and are considered to have been rendered non-effective only on the 1-1/8" thickness of armor plate. Although one of these bombs had its nose section cracked open after penetrating 1" plate, it is quite certain from the appearance of the nose section and cap (Figure 6) that it was the secondary impact on the butt wall behind the target that rendered it non-effective. This conclusion was substantiated when a second National Tube bomb was fired at 1" plate and recovered intact (Figure 8). All impacts were at a velocity of approximately 1000 ft/sec, which would roughly correspond to a drop from 25,000 ft. altitude. In each case the target was at an obliquity of 20° to the line of fire (as measured from the normal).

Round 1

Previous tests of experimental models of the 500 lb. Mk 82 bomb, references (b) and (c), had indicated that the bomb would occasionally penetrate a target as heavy as 1-1/4" STS at 20° obliquity at 1000 ft/sec. Therefore, it was felt that 1-1/8" STS would be a fair, although severe, initial target for the test bombs. Since the National Tube bombs were received first, one of this manufacture was used for round number 1 in the program. It penetrated the 1-1/4" STS target and left a normal sized opening, 10-1/2" x 10-1/2". It was recovered approximately 40 feet behind the target, deeply embedded in some hard clay, having turned downwards in the sand. The nose plug was still in place but a longitudinal crack completely through the side wall had developed, starting at the nose and running aft for 20", (Figure 3). Since the crack extended into the cavity the bomb was considered non-effective.

Round 2

A Lyon bomb was then fired at the same target for comparison purposes. Pieces of it were recovered a short distance behind the target. The short recovery distance plus the large size of the hole produced in the target, 13" x 15", indicated that the bomb had broken up before getting completely through the 1-1/8" plate, (Figure 4).

Round 3

The target thickness was reduced to 1" for the next National Tube bomb. The appearance of the impact was such that some bomb yaw was suspected. The sharp change of direction of the bomb after target penetration, resulting in a severe secondary impact on the heavy side wall of the butt, lends further support to this suspicion. The secondary impact is definitely believed to be responsible for the failure and opening up of nose section (Figures 5 and 6). The deformation of the nose and shear type abrasion of the nose plug are much more severe than would be expected on an STS target of this thickness.

Round 4

A Lyon bomb was fired at the 1" target for comparison with the preceding shot. This bomb had a good impact. However, when recovered it was found to have failed badly, with the forward section folded back and a large section of one side completely broken away. It seems quite certain that this bomb would have deflagrated behind the target if it had been explosive loaded.

Round 5

Since the previous National Tube bomb had not had a fair test on 1" plate, this target condition was repeated. This time it received a good impact and was recovered intact with the exception of the nose plug having been wiped off. The sides of the bomb were gouged slightly by the spurs on the plate resulting from the impact, but the deformation could not be considered as serious.

Round 6

The third Lyon bomb was fired at a lighter target than any of the five previous bombs, 3/4" STS. It was recovered in pieces and apparently, as judged by the size of the impact dimensions on the plate, had started to fail before it was completely through the target. Since a plate penetration limit below 3/4" thickness would have been of little interest, the firing tests were discontinued at this time.

Metallurgical Tests:

One unfired bomb of each type was used for metallurgical investigation. The tests of each bomb consisted of chemical and spectrographical analysis, tensile strength, Charpy impact, Brinell hardness, hot acid etch and microscopic examination. The locations of these tests are shown in Figures 11 and 12, Appendix E.

The results of chemical and spectrographic analyses taken from the nose, front ring, back ring and tail of each bomb are shown in Table 8, Appendix E. These results indicate that the Lyon bomb was made from a semi-killed AISI-C-1030 steel and the National Tube bomb had a composition comparable to silicon killed AISI-C-1027 steel with the manganese somewhat on the low side. Only traces of other alloying elements were found in either bomb.

Standard longitudinal Charpy V-notch impact specimens, with notches perpendicular to the bomb surface (radial), were cut in duplicate at four points around the circumference of the bombs (at 1:30, 4:30, 7:30, and 10:30) from the nose, front, back and base (tail) rings as shown in Figures 11 and 12, Appendix E. The specimens cut at 1:30 in each ring were tested at room temperature (70°F or 21°C), those from the 4:30 location at 30°F (-1°C), 7:30 at -5°F (-20°C) and 10:30 at -40°F (-40°C). The results of these tests are shown in Table 9 and Figure 13, Appendix E. The broken specimens are shown in Figure 14.

In the nose section, at all testing temperatures, the Lyon bomb is very brittle, showing a crystalline fracture and low impact strength even at room temperature. In comparison, the nose of the National Tube bomb, although not good, shows better impact strength at 70°F, 30°F and -5°F and is about

the same at -40°F. Its fracture is also predominantly crystalline at all testing temperatures. In the front ring sections both bombs have about the same impact strength at 70°F and 30°F, while the Lyon bomb has somewhat better strength at -5°F and -40°F. The Lyon bomb is mostly fibrous in this section and the National Tube bomb has a great percentage of crystalline structure. The back and base sections of both bombs have approximately equal impact values at 70°F, while at all other testing temperatures the Lyon bomb is somewhat superior in both impact resistance and in fracture appearance.

Charpy impact tests were made at 70°F on the nose sections of the three Lyon bombs which broke up on plate penetration tests, with the following results:

Impact No. 43503 - 15 ft. lbs. - 85% crystalline fracture

Impact No. 43516 - 13/15 ft. lbs. - 95% crystalline fracture

Impact No. 43519 - 15 ft. lbs. - 85% crystalline fracture

These results are similar to those obtained on the unfired Lyon bomb and indicate that it, too, would probably have broken up if it had been subjected to gunfire test.

Standard .505" longitudinal tensile tests were made, one each at 12:00, 3:00, 6:00 and 9:00 o'clock locations on the nose sections of each bomb. Standard .250" tests were made at the same relative locations on the front ring (#2 in Figure 11), back ring (#3) and the tail or base ring (#4). The results of these tensile tests are shown in Table 10, Appendix E. The Bureau of Ordnance specification for tensile properties are as follows:

Yield Strength .2% Offset - psi	Ultimate Tensile Strength - psi	Elong. % in 4" Diam.	Red. Area %
70,000 min.	105,000 min.	16.0 min.	Not spec.

The Lyon bomb was below specification in tensile strength in the nose section and in elongation in all sections. The Lyon elongations were especially low in the nose and tail sections but part of this was because the tests fractured close to the gauge marks. All four tensile tests in the nose section broke

in the same relative area, which was approximately 3-1/4" from the end of the bomb. The same phenomenon occurred in the tail tests, which all fractured approximately 3" from the end of the bomb indicating rings of weakness in those areas near the ends of the bomb.

The National Tube bomb was below specification only in yield and ultimate strengths in the nose section. All of the other tensile properties were satisfactory, although the elongation in the tail section was borderline.

The high yield strength and low elongation and reduction of area shown by the Lyon bomb are typical of cold worked material and indicate that this bomb lacks some of the ductility shown by the National Tube bomb. However, the Lyon bomb was very uniform in properties around the circumference while the National Tube bomb, except in the nose section, varied greatly in the same ring, as much as 28400 psi in yield strength and 22900 psi in tensile strength. The Lyon bomb also has greater uniformity from nose to tail, the greatest variation in tensile strength being 15000 psi whereas the National Tube bomb has a spread of 32900 psi.

Brinell hardness tests were made on transverse rings cut from the nose, front, back and tail sections of each bomb and also on longitudinal strips 180° apart (at 1:30 and 7:30) from nose to tail of each bomb. The readings on the Lyon transverse rings were taken only at four points 90° apart because it was felt that more readings were superfluous since the values were so uniform. However, the values obtained at the quarter points on the National Tube bomb were so erratic that readings were taken at twelve equally spaced points around the circumference. On the longitudinal strips tests were made every inch for the length of the bombs. The results of the transverse and longitudinal tests are shown in Tables 11 and 12 respectively, Appendix E. A summary of the hardness tests is shown below:

B.H.N. - Transverse Rings

Test Location	Lyon Bomb Average	Lyon Bomb Range	National Tube Bomb Average	National Tube Bomb Range
Nose	209	207-212	205	195-212
Front	233.5	229-241	253	228-285
Back	226	223-229	236	212-282
Tail	232.5	229-237	245	207-269

B.H.N. - Longitudinal Strips

Manufacturer	Location	Average	Range
Lyon	1:30	232	203-245
Lyon	7:30	232.6	203-245
National Tube	1:30	239.3	179-282
National Tube	7:30	238.6	183-280

In average overall hardness the National Tube bomb is slightly harder than the Lyon bomb. Both bombs have about the same hardness in the nose. In the front, back and tail sections the average hardness of the National Tube bomb is higher than the Lyon bomb, but there is a much greater variation in the National Tube bomb. As in tensile properties, the hardness tests also show that the Lyon bomb is more uniform around the circumference as well as from end to end.

The transverse rings and the longitudinal strips used for the hardness tests were also used for hot acid etch tests. The etching solution consisted of 50% HCl and 50% water at a temperature of 160°F. The etching time was approximately 20 minutes. Photographs of the etched specimens are attached as Figures 15 to 26 inclusive in Appendix E. The Lyon bomb specimens have a moderate degree of porosity and segregation, which conditions are typical of semi-killed steel and are not believed to be excessive. The National Tube bomb specimens, made from killed steel, are sound and show no segregation.

In comparing the contours of the etched rings, especially the nose rings in Figures 15 and 19, a notable difference can be discerned in the uniformity of the walls of the two bombs, the Lyon bomb being very concentric and the National Tube bomb having a somewhat irregular inside surface.

Figures 23 and 24 reveal that the base of the National Tube bomb has been attached by welding from the outside, leaving an open crack on the inside which could have a notch effect in starting a fracture. The Lyon bomb base, Figures 25 and 26, is an integral part of the bomb and could be expected to show better service performance.

Microscopic examination was made on longitudinal specimens using the broken Charpy specimens taken at 1:30 location in the nose, front, back and tail rings. Typical non-metallic inclusions are shown in Figures 27 to 30 inclusive for the Lyon bomb and in Figures 31 to 34 inclusive for the National Tube bomb. These inclusions are not excessive for the types of steel represented. Figures 35 to 38 inclusive show the Lyon bomb structures at a magnification of 100X and Figures 43 to 46 inclusive show the same specimens at 500X. These photomicrographs represent a processed structure (cold worked after a partially spheroidize anneal). The grains are elongated by cold working, Figures 37 and 45 (back section), showing the most cold work and Figures 35 and 43 (nose section) showing the least amount of cold work. Figures 39 to 42 inclusive (at 100X) and 47 through 50 (at 500X) show the quenched and drawn structure of the National Tube bomb. These structures consist of tempered martensite, bainite and ferrite and indicate incomplete quench hardening which is most evident in the nose section. The grains are rather coarse and the presence of ferrite in the grain boundaries has a tendency to lessen the toughness of the steel.

Metallurgical comparison of the two bombs revealed the following:

a. The National Tube bomb was made from a better grade of steel.

b. The nose of the Lyon bomb was considerably more brittle than that of the National Tube bomb as indicated by Charpy impact tests.

c. The ductility of the National Tube bomb was greater than that of the Lyon bomb as shown by tensile tests.

d. The average hardness of the National Tube bomb was higher than for the Lyon bomb but the Lyon bomb was more uniform.

e. Both bombs were satisfactory for soundness and segregation on hot etch tests, the National Tube bomb being slightly superior in these respects.

f. The Lyon bomb was more uniform in contour of section and had a better design in the base (weld eliminated).

g. The Lyon bomb had a spheroidized annealed and cold drawn microstructure while the National Tube bomb showed a quenched and drawn heat treated structure.

CONCLUSIONS

On the basis of the comparison firing tests conducted at 1000 ft/sec on the Lyon Incorporated bombs made from cold formed, commercial steel plate and the National Tube Division bombs made by conventional methods from high manganese, steel tubing, the following conclusions are drawn:

	Lyon	National Tube
Terminal Ballistics Properties:	Poor	Average for 500 lb. GP low drag bombs.
Plate Penetration Limit at 1000 ft/sec:	<3/4" STS at 20° obliquity.	1" STS at 20° obliquity.
Deformation:	Break up on 3/4" or heavier STS plates.	Slight side wall deformation on 1" STS plate which is probably not serious enough to deflagrate an HE loaded bomb.

The metallurgical tests indicate that the failure of the Lyon bomb was caused by lack of ductility and toughness, particularly in the nose section of the bomb.

RECOMMENDATIONS

Improvement of the Lyon Incorporated bombs can probably be effected by changing to a steel which will permit heat treatment. Higher impact strength is believed necessary for the material to enable the bombs to withstand the high deceleration forces encountered on plate impacts.

REFERENCES

(a) BUORD Conf ltr Re3c/Re3d-LME:ANB;ehr X5/2 Ser 12960 of 9 Dec 1955
(b) NGP Conf Report 1299 of 18 Oct 1954
(c) NPG Conf Report 1311 of 8 Dec 1954

APPENDIX A

TABLE 1

SUMMARY OF FIRING CONDITIONS

Date Fired	Impact Number	Rd. No.	Obl.	Thickness	Bomb Mfg.	S.V. (f/s)	Bomb Wt.	Pene.	Through Opening	Inert Filler Date Loaded	Remarks
1955										1955	
12/22	43492	1	20°	1-1/8"STS	National Tube Div.	929	504#	Comp.	10-1/2"x10-1/2	12/15	Ineffective; bomb cracked longitudinally for a distance of 20" from nose.
12/29	43503	2	20°	1-1/8"STS	Lyon Inc.	945	503#	Comp.	13" x 15"	12/20	Ineffective; Bomb broke up on plate.
1956											
1/3	43515	3	20°	1" STS	National Tube Div.	929	501#	Comp.	13" x 14"	12/15	Ineffective; Bomb badly damaged as a result of secondary impact on butt wall.
1/5	43516	4	20°	1" STS	Lyon Inc.	977	502#	Comp.	11" x 11-1/2"	12/20	Ineffective; Good impact, bomb broke up behind target.
1/6	43518	5	20°	1" STS	National Tube Div.	1019	503#	Comp.	12" x 16"	12/15	Effective and intact, nose cap missing.
1/9	43519	6	20°	3/4"STS	Lyon Inc.	989	508#	Comp.	12" x 12-1/2"	12/20	Ineffective; bomb broke up.

APPENDIX B

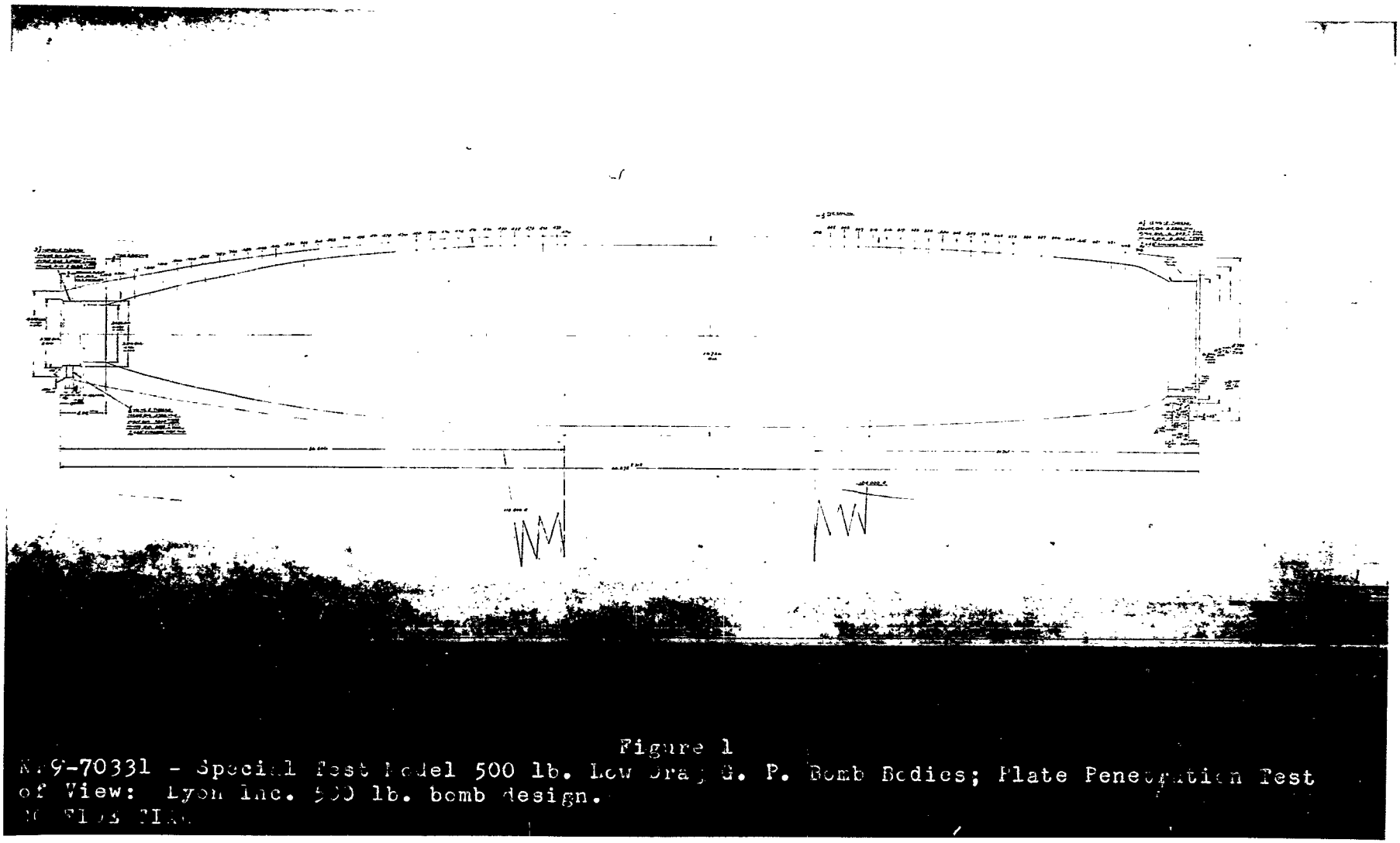

Figure 1

M-9-70331 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies; Plate Penetration Test
of View: Lyon Inc. 500 lb. bomb design.

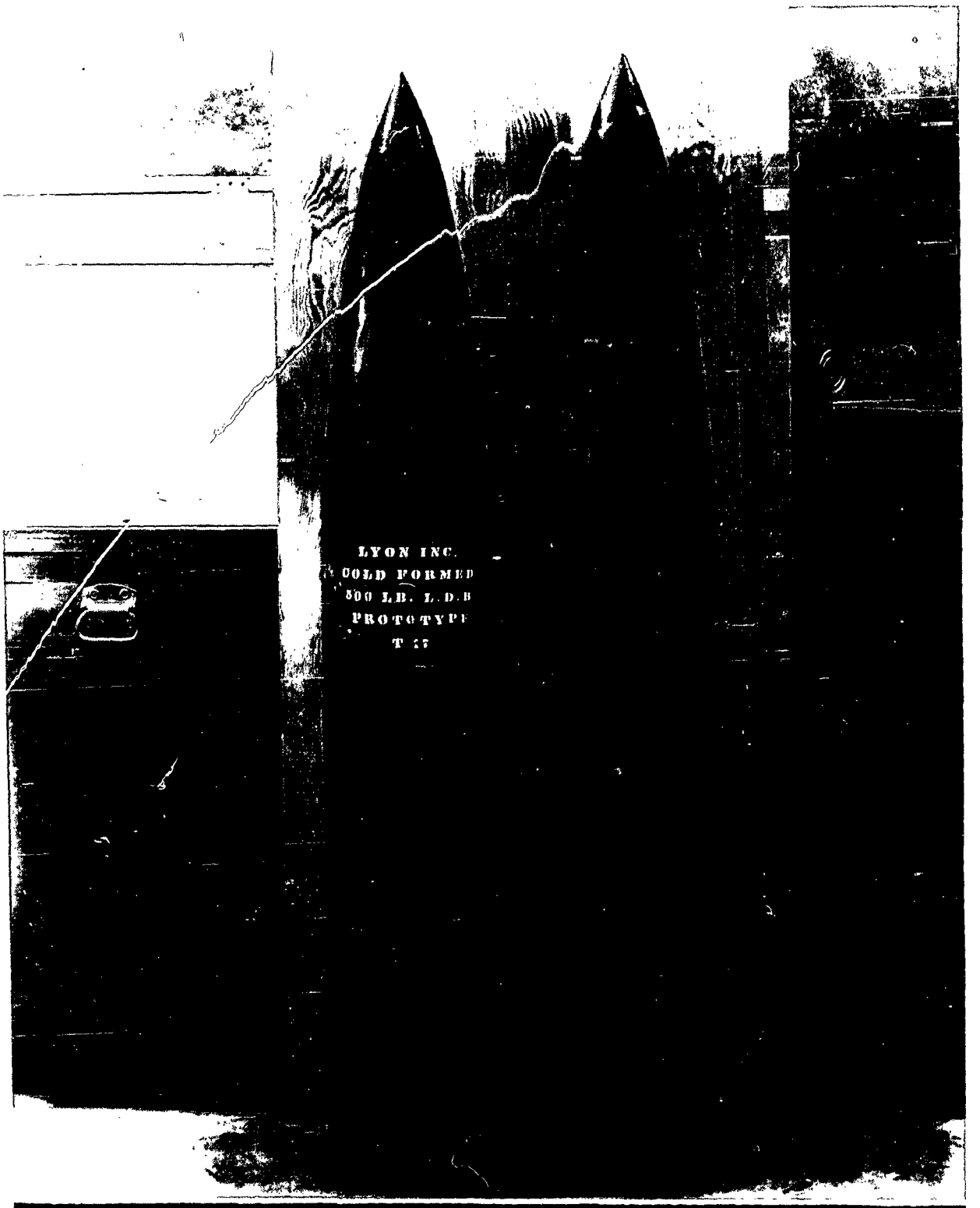

Figure 2
(P9-70332 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies; Plate Penetration Test of View: Comparison of Lyon Inc. and National Tube Div. bombs used in test.
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APPENDIX C

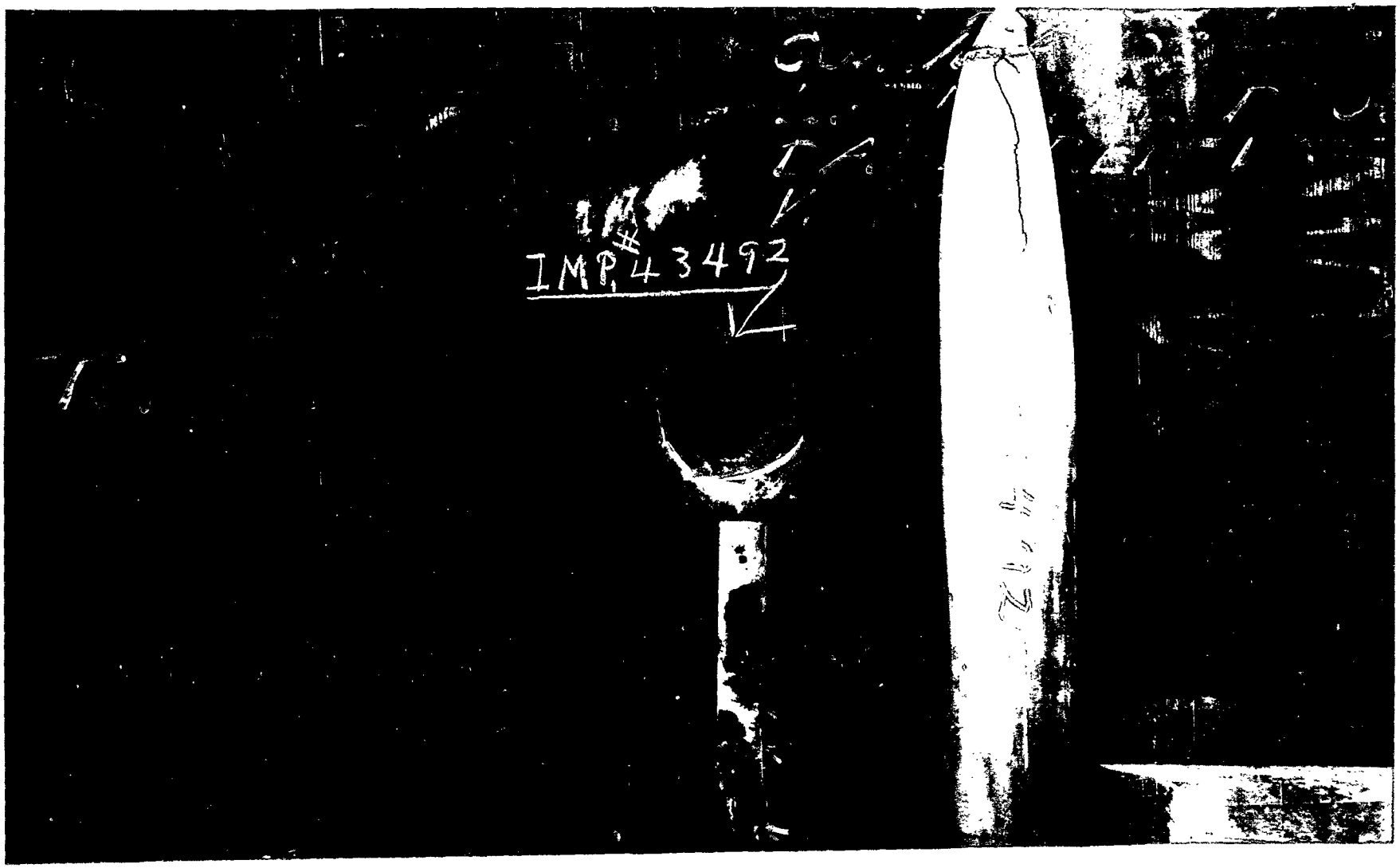

Figure 3

NP9-70333 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies; Plate Penetration Test of:

Impact No.	Obl.	Target	Vel.	Bomb Wt.	Bomb Mfr.	Pene.	Remarks
43492	20°	1-1/8" STS	929 f/s	504#	Nat'l. Tube Div.	Comp.	Ineffective; Bomb cracked longitudinally for a distance of 20" from nose.

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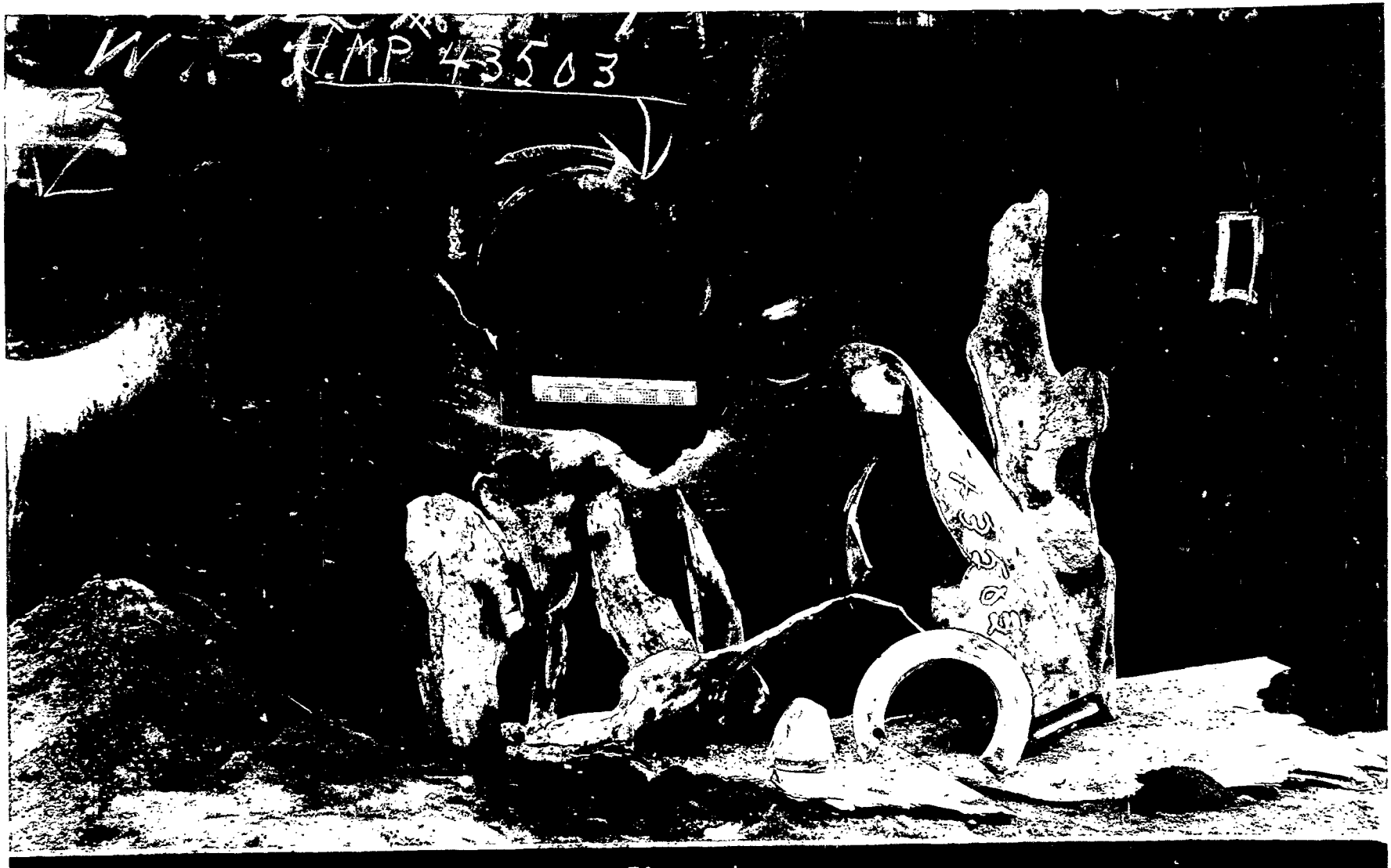

Figure 4

NP9-70225 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies, Plate Penetration

Test of:

Impact No.	Obl.	Target	Vel.	Bomb Wt.	Bomb Mfg.	Pene.	Remarks
43503	20°	1-1/8"STS	945 f/s	503#	Lyon Inc.	Comp.	Ineffective; Bomb broke up on plate.

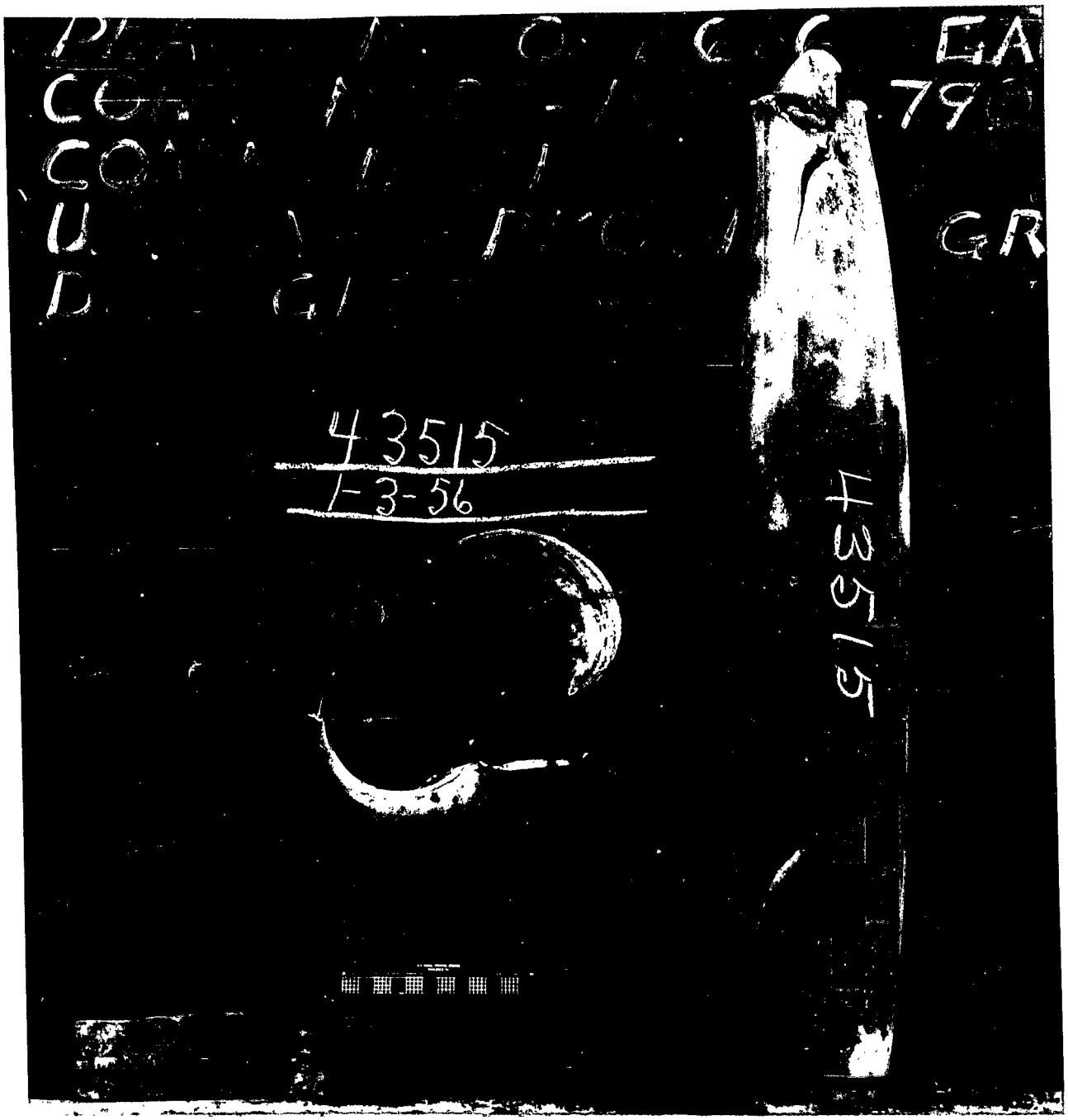

Figure 5

AF9-70334 - Spec[illegible] Model 500 lb. low or[illegible]. N. Bomb
Bodies; Plate [illegible] Oblique Test of:

Impact No.	Obl.	[illegible]	[illegible]	[illegible]	Bomb Mfg.	Bomb Name	[illegible] lbs
43515	20°	1st [illegible]	[illegible]	501	Pat'l. Pump. Tube Div.	Ineffective; bomb [illegible] as [illegible] section	

[illegible] 3 January 1956

Figure 6

XP9-70335 - Special ... Model 500 lb. ... Bomb Bodies; Plate Penetration Test of:

Impact No.	Obl.	Target	Vel.	Bomb Wt.	Bomb ...	Pene.	Remarks
43515	20°	1" ...	... f/s	501	Nat'l. Tube Div.	Comp.	Ineffective; bomb ... as a result of ... on ...

... NSI ... FIAI

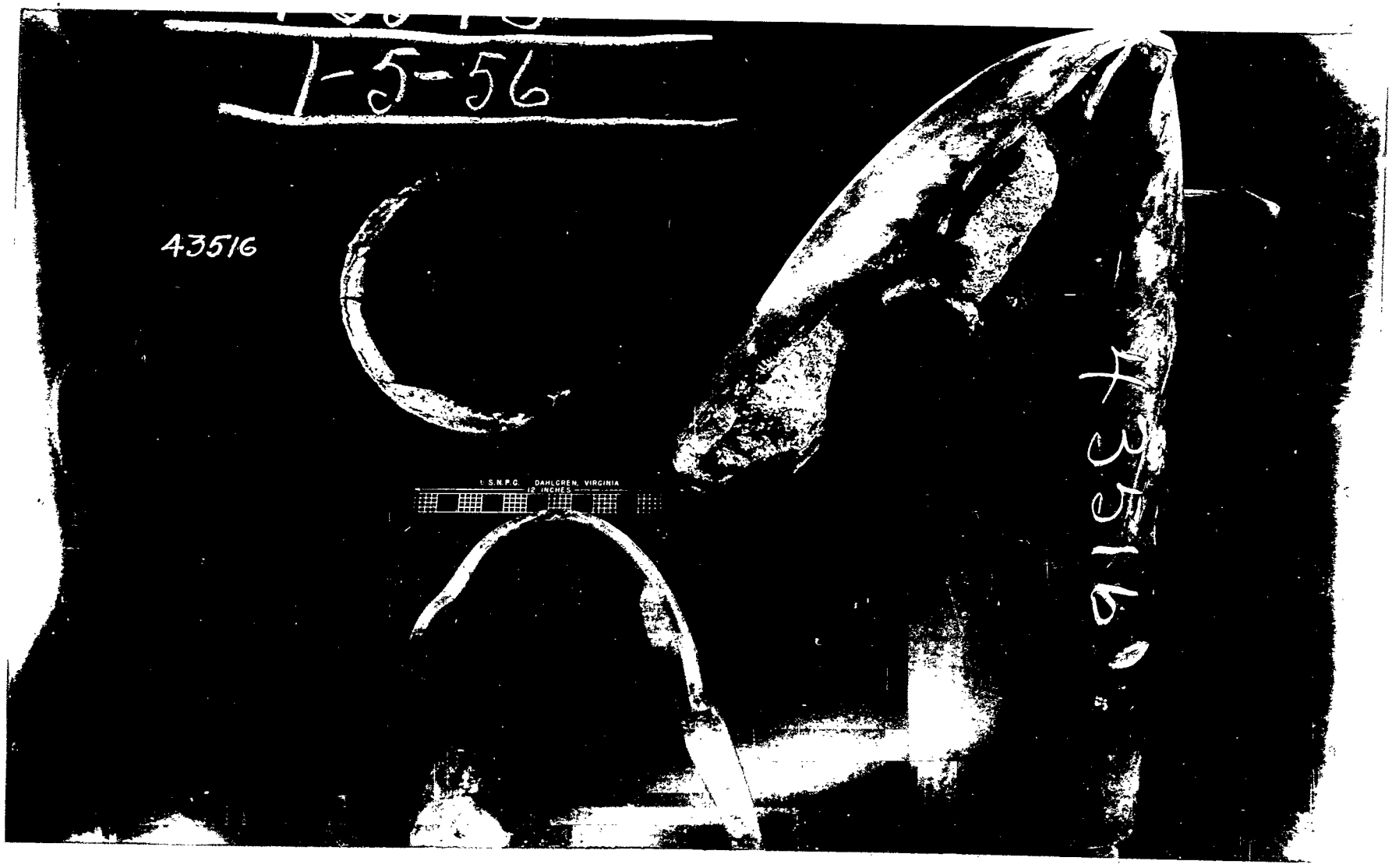

Figure 7

NP9-70226 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies, Plate Penetration Test of:

Impact No.	Obl.	Target	Vel.	Bomb Wt.	Bomb Mfg.	Pene.	Remarks
43516	20°	1" STS	977 f/s	502#	Lyon Inc.	Comp.	Ineffective; Good impact, bomb broke up behind target.

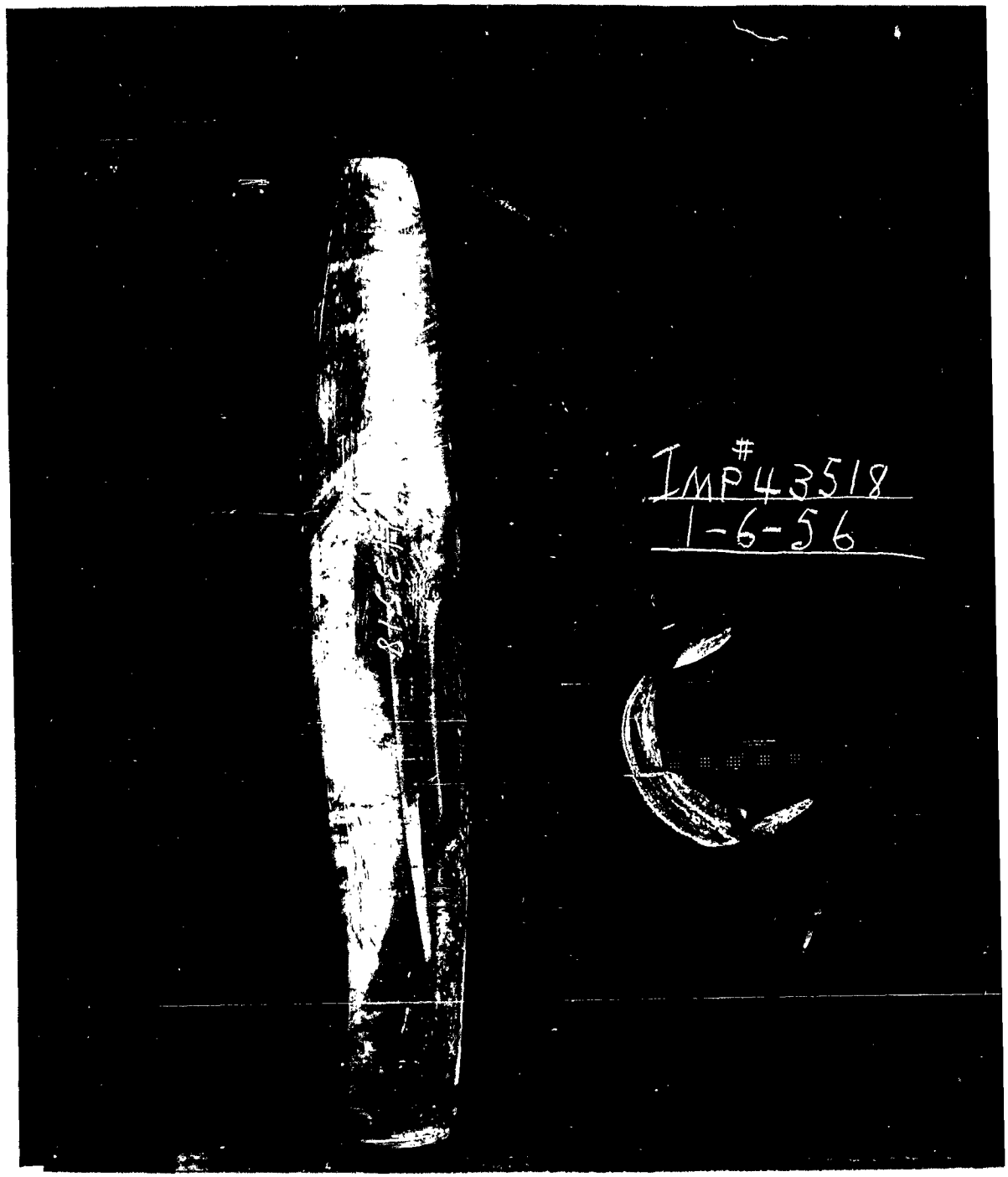

Figure 8

NP9-70227 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies, Plate Penetration Test of:

Impact No.	Obl.	Target	Vel.	Bomb Wt.	Bomb Mfg.	Pene.	Remarks
43518	20°	1" STS	1019 f/s	503#	Nat'l. Tube Div.	Comp.	Effective and intact. Nose cap missing.

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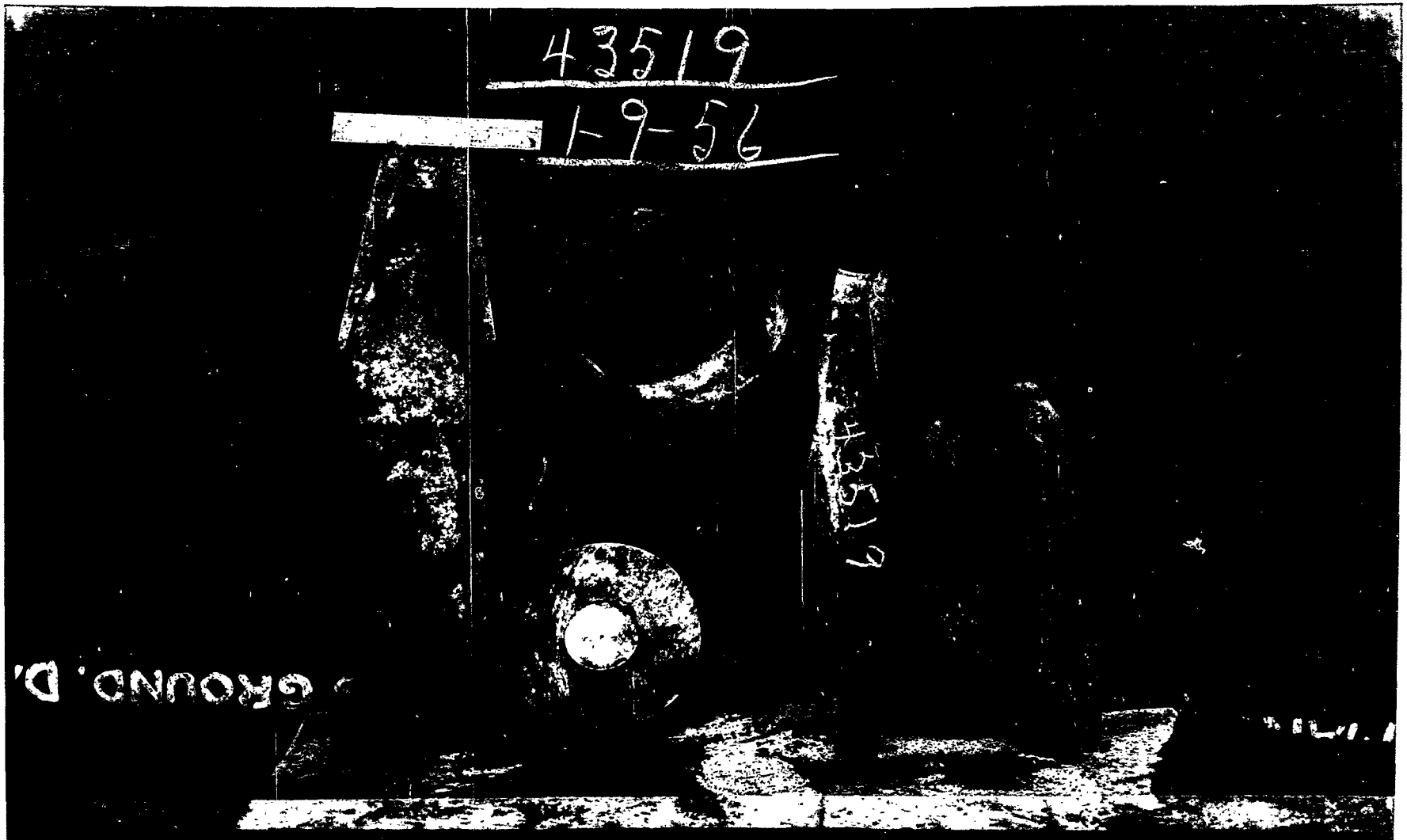


Figure 9

NP9-70228 - Special Test Model 500 lb. Low Drag G. P. Bomb Bodies, Plate Penetration

Test of:

Impact No.	Qbl.	Target	Vel.	Bomb Wt.	Bomb Mfg.	Pene.	Remarks
43519	20°	3/4" STS	989 f/s	508#	Lyon Inc.	Comp.	Ineffective; bomb broke up.

APPENDIX D

CONFIDENTIAL
BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:ANB:ehr
Ser 12960 of 9 Dec 1955

Rd. #1

TEST OBJECT

Plate Penetration of 500 lb. G. P. Bomb

IMPACT NUMBER: 43492
DATE OF IMPACT: 12-22-55
BUTT NO.: B

PLATE		BOMB XXXXXXX	
GAUGE: 1.10"	CLASS: STS	CALIBER: 500#	TYPE: G. P. Low Drag
MANUFACTURER: U. S. Steel	CONTRACT: N600-1555-29313	MANUFACTURER: N.T. Co.	LOT NO.: 68
GROUP: U-154-48	NO.: 076162	MARK: 82	MOD.: 1
DIMENSIONS: 95" x 250"		PROJECTILE NO.: 384	YEAR OF SPECIFICATION: -
IMPACT DATA		CAPPED: ☐ YES ☐ NO	LENGTH (Uncapped): -
OBLIQUITY: 20°	PENETRATION: Complete	WEIGHT (Capped):	WEIGHT (Uncapped): -
THICKNESS AT IMPACT: 1.10"	NO. OF IMPACT ON PLATE: 3	FUZE: None	FILLER: 1.55 Density Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 128"	THROUGH OPENING: 10-1/2"x10-1/2"	CONDITION AFTER FIRING: ☐ EFFECTIVE ☒ INEFFECTIVE	
DISTANCE FROM: ☒ TOP ☐ BOTTOM 50"	DISTANCE FROM: ☐ RIGHT ☒ LEFT 86"	Bomb cracked longitudinally for a	
FLAKING FRONT: 0"	FLAKING BACK: 0"	distance of 20" from nose. (Shown	
SPUR: 7"	DISH: 3"	on Figure 3, photograph NP9-70333.)	
CRACKS: 0"	BULGE: 0"		
BUTTON: ☒ THROWN ☐ STARTED			

Impact Dim. 11" x 12"

VELOCITY (F.S.)

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 929

REMARKS

1. Drop - 0"
2. Gun Pressure: 5.4 tsi
3. Base of bomb seated 98"
4. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d,θ)	RECOMMENDATION
		☐ ACCEPT ☐ REJECT

SIGNATURE	TITLE
G. J. MISKHO	LTJG, USNR, FIRING OFFICER

CONFIDENTIAL

BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:ANB:ehr
Ser 12960 of 9 Dec 1955

Rd. #2

IMPACT NUMBER: 43503
DATE OF IMPACT: 12-29-55
BUTT NO.: B

TEST OBJECT

Plate Penetration of 500 lb. G. P. Bomb

PLATE		BOMB ~~PROJECTILE~~	
GAUGE: 1-1/8"	CLASS: STS	CALIBER: 500#	TYPE: G. P. Low Draz
MANUFACTURER: U. S. Steel	CONTRACT: N600-465E-29313	MANUFACTURER: Lyon Inc.	LOT NO.: -
GROUP: U-154-48	NO.: 076162	MARK: 82	MOD.: 0
DIMENSIONS: 95" x 250"		PROJECTILE NO.: 298 - T17	YEAR OF SPECIFICATION: -
IMPACT DATA		CAPPED ☐ YES ☐ NO	LENGTH (Uncapped): -
OBLIQUITY: 20°	PENETRATION: Complete	WEIGHT (Capped):	WEIGHT (Uncapped): -
THICKNESS AT IMPACT: 1-1/8"	NO. OF IMPACT ON PLATE: 4	FUZE: None	FILLER: 1.55 Density Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 36"	THROUGH OPENING: 13" x 15"	CONDITION AFTER FIRING ☐ EFFECTIVE ☒ INEFFECTIVE	
DISTANCE FROM ☒ TOP ☐ BOTTOM 51"	DISTANCE FROM ☐ RIGHT ☒ LEFT 120"	Bomb broke up on plate. (Shown on	
FLAKING FRONT: 0"	FLAKING BACK: 0"	Figure 4, photograph NP9-70225.)	
SPUR: 16"	DISH: 3"		
CRACKS: 0"	BULGE: 0"		
BUTTON ☐ THROWN ☐ STARTED			

Impact Dim 19" x 21"

VELOCITY (F.S.)

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 940

REMARKS

1. Drop - 0"
2. Gun Pressure: 1.8 tsi
3. Base of bomb seated 98"
4. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d, θ)	RECOMMENDATION ☐ ACCEPT ☐ REJECT

SIGNATURE	TITLE
G. J. MISKHO	LTJG, USNR, FIRING OFFICER

CONFIDENTIAL

TABLE 3

NAVY-DPPO PRNC, WASH., D.C.

CONFIDENTIAL

BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:ANF:ehr
Ser 12960 of 9 Dec 1955

Rd. #3

IMPACT NUMBER	DATE OF IMPACT	BUTT NO.
43515	1-3-56	B

TEST OBJECT

Plate Penetration of 500 lb. G. P. Bomb

PLATE		BOMB ~~XXXXXX~~	
GAUGE: 1"	CLASS: STS	CALIBER: 500#	TYPE: G. P. Low Drag
MANUFACTURER: U. S. Steel	CONTRACT: N600-1555-38790	MANUFACTURER: N.T. Co.	LOT NO.: 68
GROUP: U-154-246	NO.: 052666	MARK: 82	MOD.: 1
DIMENSIONS: 93" x 320"		PROJECTILE NO.: 386	YEAR OF SPECIFICATION: -
IMPACT DATA		CAPPED ☐ YES ☐ NO	LENGTH (Uncapped): -
OBLIQUITY: 20°	PENETRATION: Complete	WEIGHT (Capped):	WEIGHT (Uncapped): -
THICKNESS AT IMPACT: 1"	NO. OF IMPACT ON PLATE: -	FUZE: None	FILLER: 1.55 Density Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 132"	THROUGH OPENING: 13" x 14"	CONDITION AFTER FIRING: ☐ EFFECTIVE ☒ INEFFECTIVE	
DISTANCE FROM: ☒ TOP ☐ BOTTOM 54"	DISTANCE FROM: ☐ RIGHT ☒ LEFT 154"	Bomb badly damaged as a result of	
FLAKING FRONT: 0"	FLAKING BACK: 0"	secondary impact on butt wall.	
SPUR: 6"	DISH: 4"	(Shown on Figures 5 and 6, photo-	
CRACKS: 0"	BULGE: 0"	graphs NP9-70334 and NP9-70335.)	
BUTTON: ☒ THROWN ☐ STARTED			

VELOCITY (F.S.)

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 929

REMARKS

1. Gun Pressure: 1.5 tsi
2. Base of bomb seated 98"
3. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d, θ)	RECOMMENDATION
		☐ ACCEPT ☐ REJECT

SIGNATURE	TITLE
G. J. MISKHO	LTJG, USNR, FIRING OFFICER

NAVY-DPPO PRNC, WASH., D.C.

CONFIDENTIAL
BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:AND:ehr
Ser 12960 of 9 Dec 1955

Ed. #4

IMPACT NUMBER: 43516
DATE OF IMPACT: 1-5-56
BUTT NO.: P

TEST OBJECT: Plate Penetration of 500 lb. G. P. Bomb

PLATE

GAUGE	CLASS
1"	STS
MANUFACTURER	CONTRACT
U. S. Steel	N600-1559-38790
GROUP	NO
U-154-246	052666
DIMENSIONS	
96" x 320"	

IMPACT DATA

OBLIQUITY	PENETRATION
20°	Complete
THICKNESS AT IMPACT	NO. OF IMPACT ON PLATE
1"	4
DISTANCE FROM NEAREST IMPACT	THROUGH OPENING
53"	11" x 11-1/2"
DISTANCE FROM [X] TOP [ ] BOTTOM 52"	DISTANCE FROM [ ] RIGHT [X] LEFT 96"
FLAKING FRONT	FLAKING BACK
0"	0"
SPUR	DISH
7"	3"
CRACKS	BULGE
0"	0"
BUTTON [X] THROWN [ ] STARTED	

BOMB XXXXXXX

CALIBER	TYPE
500#	G. P. Low Drag
MANUFACTURER	LOT NO.
Lyon Inc.	-
MARK	MOD.
32	0
PROJECTILE NO.	YEAR OF SPECIFICATION
T14	-
CAPPED [ ] YES [ ] NO	LENGTH (Uncapped)
	-
WEIGHT (Capped)	WEIGHT (Uncapped)
	-
FUZE	FILLER
None	1.55 Density Perlite-Cement-Water
CONDITION AFTER FIRING [ ] EFFECTIVE [X] INEFFECTIVE	

Bomb broke up behind target.

(Shown on Figure 7, photograph NP9-70226.)

VELOCITY (F.S.)

DESIRED	OBTAINED	
		[ ] MUZZLE [ ] STRIKING [X] MEAN 977

REMARKS

1. Gun Pressure: 2.1 tsi
2. Base of bomb seated 98"
3. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d, θ)	RECOMMENDATION
		[ ] ACCEPT [ ] REJECT

SIGNATURE	TITLE
G. J. MISKHO	LTJG, USNR, FIRING OFFICER

NAVY-DPPO PRNC, WASH., D.C.

CONFIDENTIAL

BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:ANB:ehr
Ser 12960 of 9 Dec 1955

Rd. #5

IMPACT NUMBER	DATE OF IMPACT	BUTT NO.
43518	1-6-56	B

TEST OBJECT

Plate Penetration of 500 lb. G. P. Bomb

PLATE		BOMB XXXXXXXX	
GAUGE: 1"	CLASS: STS	CALIBER: 500#	TYPE: G. P. Low Drag
MANUFACTURER: U. S. Steel	CONTRACT: N600-155S-38790	MANUFACTURER: N.T. Co.	LOT NO.: 68
GROUP: U-154-246	NO: 052666	MARK: 82	MOD.: 1
DIMENSIONS: 96" x 320"		PROJECTILE NO.: 387	YEAR OF SPECIFICATION: -
IMPACT DATA		CAPPED ☐ YES ☐ NO	LENGTH (Uncapped): -
OBLIQUITY: 20°	PENETRATION: Complete	WEIGHT (Capped):	WEIGHT (Uncapped): -
THICKNESS AT IMPACT: 1"	NO. OF IMPACT ON PLATE: 5	FUZE: None	FILLER: 1.55 Density Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 52"	THROUGH OPENING: 12" x 16"	CONDITION AFTER FIRING: ☒ EFFECTIVE ☐ INEFFECTIVE	
DISTANCE FROM ☐ TOP ☒ BOTTOM 117"	DISTANCE FROM ☐ RIGHT ☒ LEFT 55"	Bomb intact except for missing	
FLAKING FRONT: 0"	FLAKING BACK: 0"	nose plug; sides gouged slightly.	
SPUR: 8"	DISH: 2"	(Shown on Figure 8, photograph	
CRACKS: 0"	BULGE: 0"	NP9-70227.)	
BUTTON ☒ THROWN ☐ STARTED			

VELOCITY (F.S.)

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 1019

REMARKS
1. Gun Pressure: 2.4 tsi
2. Base of bomb seated 98"
3. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d, θ)	RECOMMENDATION ☐ ACCEPT ☐ REJECT

SIGNATURE	TITLE
G. J. MISKHO	LTJG, USNR, FIRING OFFICER

CONFIDENTIAL

TABLE 6

NAVY-DPPO PRNC, WASH., D.C.

CONFIDENTIAL

BUTT IMPACT RECORD
PRNC-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

NPG Report No. 1452

REF: (a) BUORD Conf ltr Re3c/Re3d:LME:AND:ehr
Ser 12960 of 9 Dec 1955

Rd. #6

IMPACT NUMBER: 43519
DATE OF IMPACT: 1-9-56
BUTT NO.: B

TEST OBJECT

Plate Penetration of 500 lb. G. P. Bomb

PLATE		BOMB PROJECTILE
GAUGE: 3/4"	CLASS: STS	CALIBER: 500# / TYPE: G. P. Low Drag
MANUFACTURER: Lukens	CONTRACT: N600-155S-38816	MANUFACTURER: Lyon Inc. / LOT NO.: -
GROUP: L122	NO: 122	MARK: 82 / MOD.: 0
DIMENSIONS: 96" x 300"		PROJECTILE NO.: T24 / YEAR OF SPECIFICATION: -
IMPACT DATA		CAPPED: ☐ YES ☐ NO / LENGTH (Uncapped): -
OBLIQUITY: 20°	PENETRATION: Complete	WEIGHT (Capped): / WEIGHT (Uncapped): -
THICKNESS AT IMPACT: .74"	NO. OF IMPACT ON PLATE: 5	FUZE: None / FILLER: 1.55 Density Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 39"	THROUGH OPENING: 12" x 12-1/2"	CONDITION AFTER FIRING: ☐ EFFECTIVE ☒ INEFFECTIVE
DISTANCE FROM: ☒ TOP ☐ BOTTOM 45"	DISTANCE FROM: ☐ RIGHT ☒ LEFT 132"	Bomb broke up. (Shown on Figure 9,
FLAKING FRONT: 0"	FLAKING BACK: 0"	photograph NP9-70228.)
SPUR: 6"	DISH: 3"	
CRACKS: 0"	BULGE: 0"	
BUTTON: ☒ THROWN ☐ STARTED		

VELOCITY (F.S.)

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 989

REMARKS

1. Gun Pressure: 2.3 tsi
2. Base of bomb seated 98"
3. No inserts in bomb

GUN: 12"/35 #19 Model 1895

e/d	F(e/d, θ)	RECOMMENDATION
		☐ ACCEPT ☐ REJECT

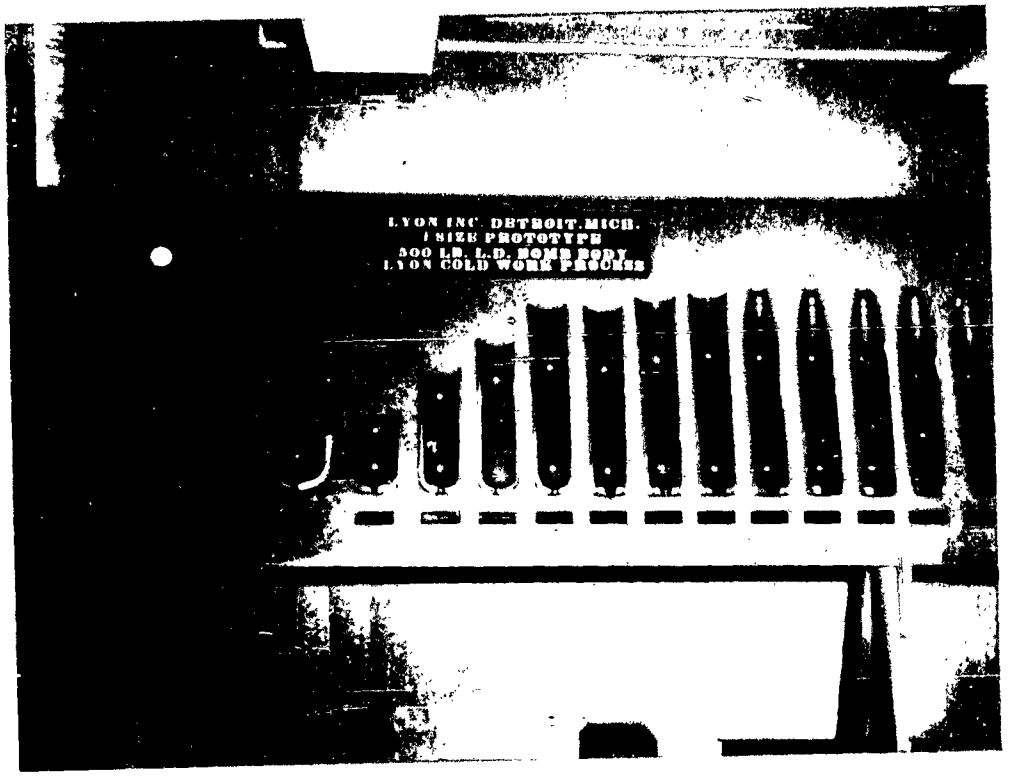
SIGNATURE: G. J. MISKHO
TITLE: LTJG, USNR, FIRING OFFICER

CONFIDENTIAL

TABLE 7

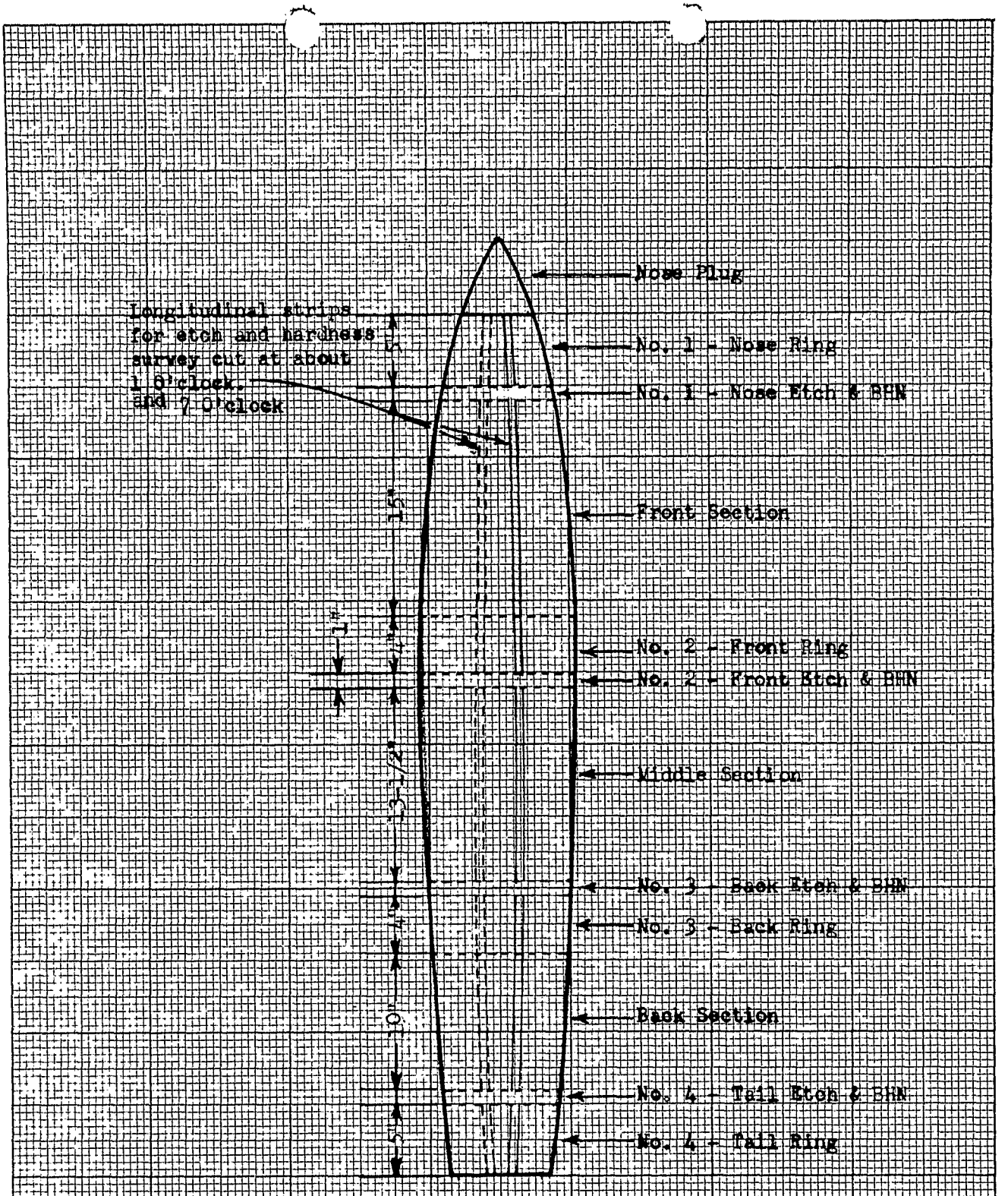
NAVY-DPPO PRNC, WASH., D.C.

APPENDIX E



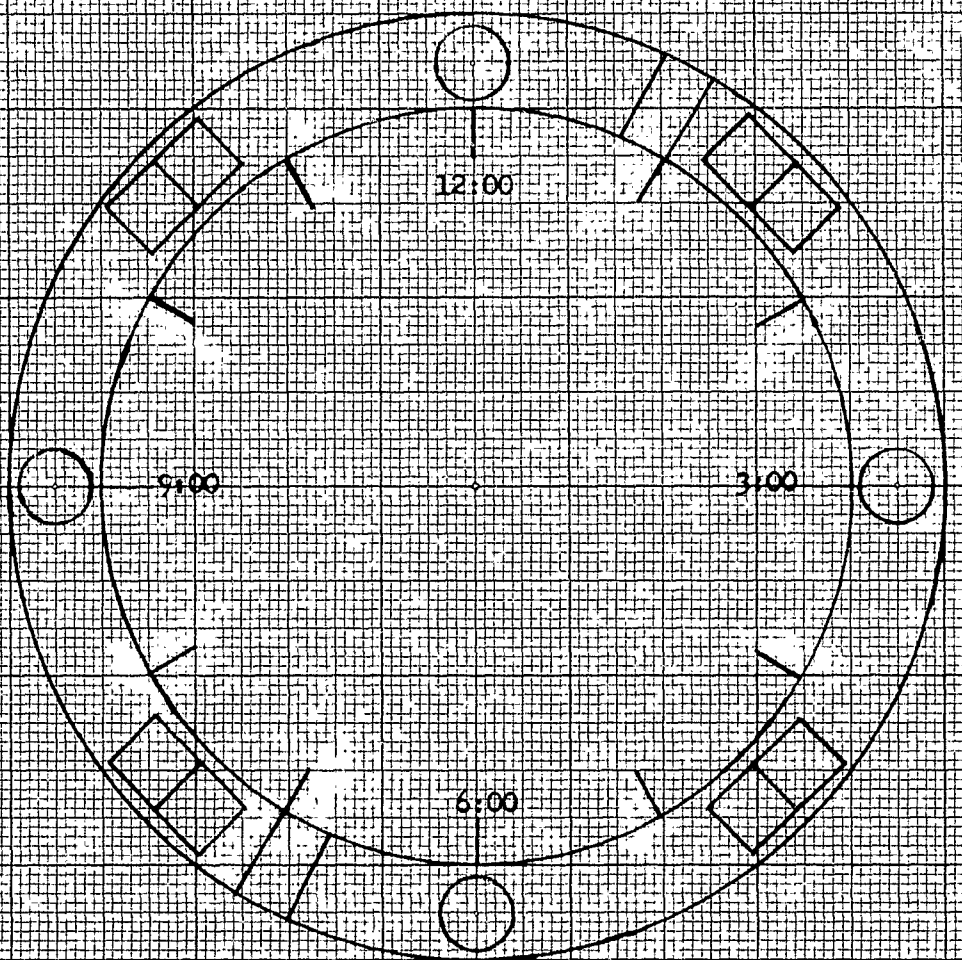
1/3 Size Prototype of the Lyon 500 Lb. Low Drag Bomb Body showing the various steps in the cold forming process.

Figure 10



500 lb. Bomb Test Locations.

Figure 11.



Longitudinal Tensile Specimens at 12:00, 3:00, 6:00 & 9:00

Longitudinal Charpy V-Notch Specimens in duplicate at 1:30, 4:30, 7:30 & 10:30.

Longitudinal Etch and Hardness Specimens at about 1:00 & 7:00

Chemical Analyses taken from 1:00 to 1:30 locations.

Location of Test Specimens from Nose, Front, Back & Tail Rings.

Figure 12.

TABLE 8 CHEMICAL COMPOSITION

Manufacturer	Location	C	Mn	P	S	Si
Lyon, Inc.	Nose	.32	.61	.011	.022	.06
Lyon, Inc.	Front	.34	.64	.012	.025	.05
Lyon, Inc.	Back	.32	.63	.012	.026	.05
Lyon, Inc.	Tail	.33	.62	.011	.025	.06
National Tube	Nose	.23	1.15	.017	.020	.13
National Tube	Front	.27	1.10	.017	.022	.11
National Tube	Back	.27	1.10	.016	.023	.13
National Tube	Tail	.27	1.14	.018	.025	.14

TABLE 9

CHARPY V-NOTCH TEST RESULTS

Manufacturer	Location	Test Temperature 70°F at 1:30 Ft. Lbs.	Fracture*	30°F at 4:30 Ft. Lbs.	Fracture	-5°F at 7:30 Ft. Lbs.	Fracture	-40°F at 10:30 Ft. Lbs.	Fracture
Lyon	Nose	14	95G	6	G	4	G	3	G
Lyon	Nose	12	95G	6	G	5	G	3	G
National Tube	Nose	26	85G	25	90G	12	G	4	G
National Tube	Nose	30	80G	23	90G	11	G	4	G
Lyon	Front	22	F	20	F	20	F	12	25G
Lyon	Front	21	F	22	F	18	5G	10	30G
National Tube	Front	20	80G	20	75G	9	95G	8	98G
National Tube	Front	22	75G	24	70G	11	90G	6	98G
Lyon	Back	26	F	26	F	20	F	19	2G
Lyon	Back	27	F	26	F	20	F	17	5G
National Tube	Back	28	60G	16	75G	8	90G	5	G
National Tube	Back	26	65G	12	85G	10	90G	7	G
Lyon	Tail	26	F	23	F	20	10G	15	25G
Lyon	Tail	26	F	24	F	18	15G	15	25G
National Tube	Tail	26	70G	18	90G	10	95G	6	98G
National Tube	Tail	33	70G	14	95G	10	95G	7	98G

* F denotes 100% fibrous fracture.
G denotes 100% granular fracture.
95G denotes 95% granular fracture.

TABLE 10

TENSILE TEST PROPERTIES

	Minimum Required	Location	Nose		Front		Back		Tail	
			Lyon	N.T.	Lyon	N.T.	Lyon	N.T.	Lyon	N.T.
Yield Strength .2% psi (1000)	70	12:00	96.8	68.7	106.8	101.8	103.5	91.6	--	93.7
		3:00	96.8	67.7	108.1	109.1	102.2	83.8	110.0	104.9
		6:00	96.8	69.9	--	80.7	101.4	92.1	110.0	88.9
		9:00	97.3	68.7	106.3	95.7	101.8	103.5	109.6	108.1
		Avg.	96.9	68.7	107.1	96.8	102.2	92.8	109.9	98.9
Tensile Strength (1000 psi)	105	12:00	102.4	100.3	113.3	123.0	110.6	116.9	116.9	119.3
		3:00	102.4	99.2	114.3	132.1	109.6	115.4	116.1	127.9
		6:00	101.9	101.9	112.8	109.2	108.4	118.5	116.1	116.4
		9:00	102.4	100.3	112.7	120.6	109.6	126.3	115.7	129.3
		Avg.	102.3	100.4	113.3	121.2	109.6	119.3	116.2	123.2
Elongation %4D	16	12:00	12.5	23.0	13.0	16.0	14.0	18.0	12.0	16.0
		3:00	12.5	23.0	13.0	17.0	15.0	19.0	11.0	16.0
		6:00	13.0	23.0	17.0	21.0	14.0	19.0	12.0	19.0
		9:00	12.0	23.0	15.0	18.0	15.0	17.0	9.0	15.0
		Avg.	12.5	23.0	14.0	18.0	14.5	18.3	11.0	16.5
Red. of Area %	Not Spec.	12:00	55.2	61.0	44.1	49.3	46.2	59.1	42.8	53.8
		3:00	54.1	60.2	43.1	54.7	42.2	52.4	35.4	49.3
		6:00	54.4	59.8	47.0	63.1	47.0	58.0	44.0	55.8
		9:00	54.7	59.4	43.8	58.5	44.6	48.3	32.8	48.1
		Avg.	54.6	60.2	44.5	56.4	45.0	54.5	38.8	51.5

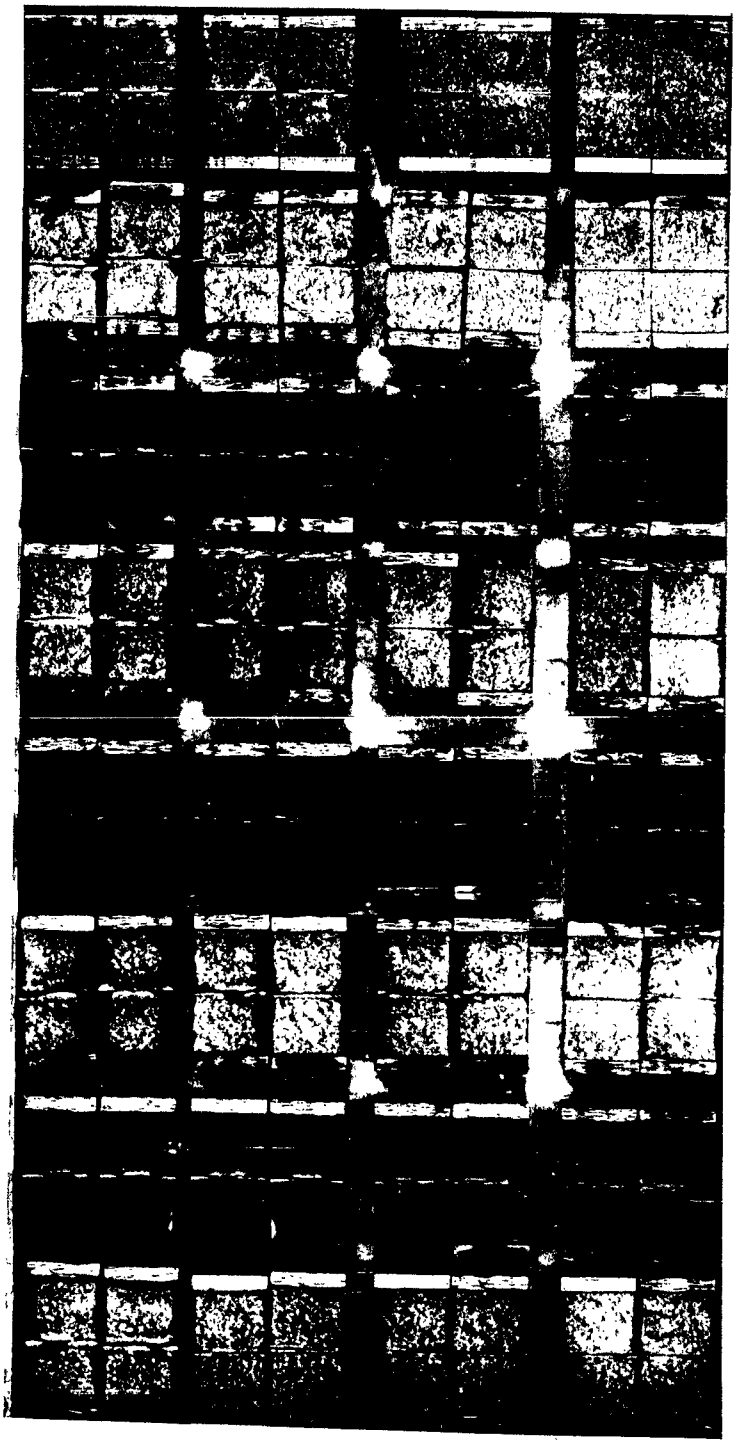
Charpy V-Notch Impact Test Results on

500 Lb. Low Drag G.P. Bombs

AP2-630 Figure 13. CONFIDENTIAL

Millimeters, soft lines heavy

70°F. 30°F. -5°F. -40°F.



Lyon
Nose Section

N.T.
Nose Section

Lyon
Front Section

N.T.
Front Section

Lyon
Back Section

N.T.
Back Section

Lyon
Base Section

N.T.
Base Section

500 Lb. Bomb Fractured Charpy Specimens

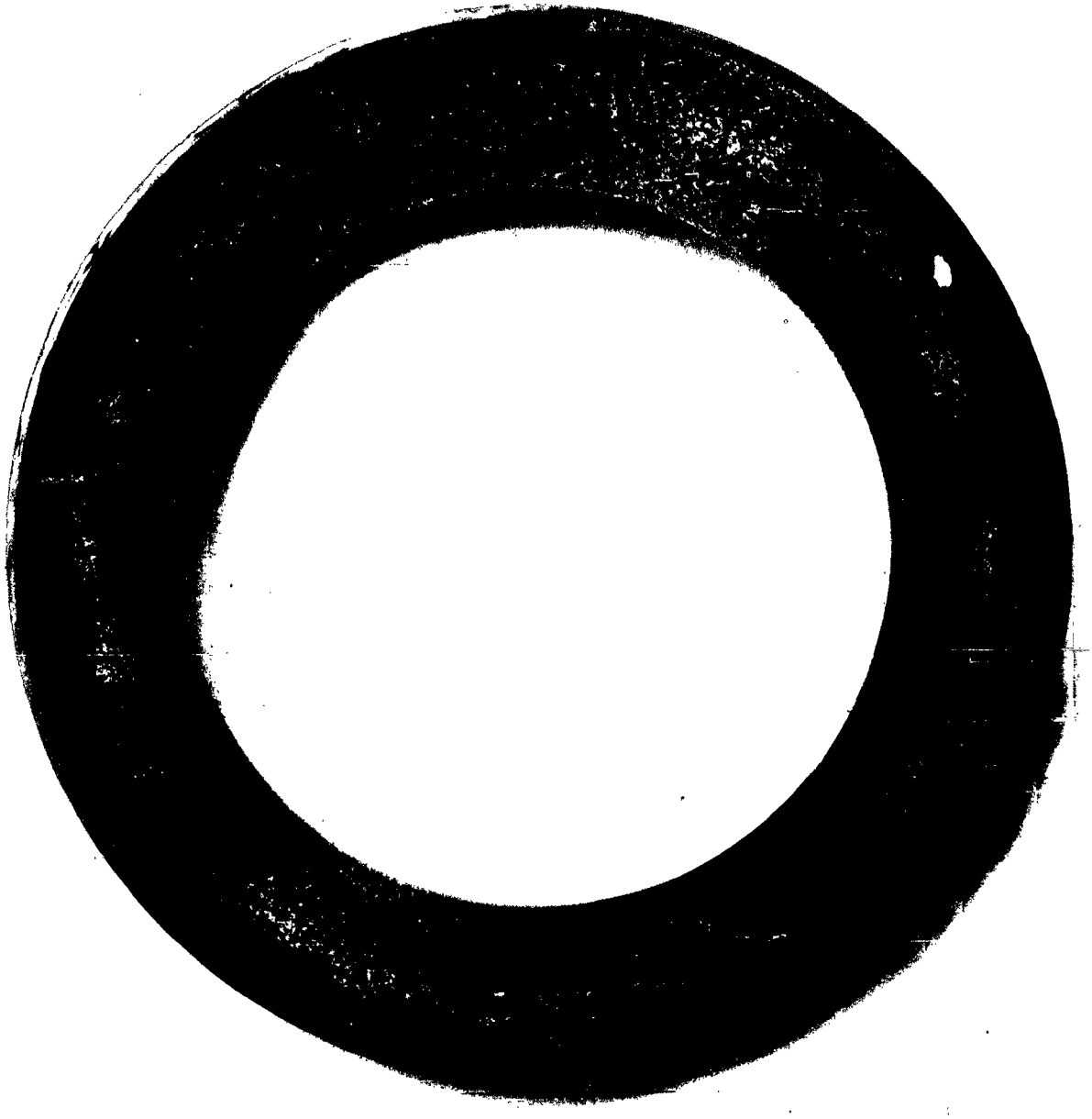
Figure 14

TABLE 11

BRINELL HARDNESS
(3000 KG.) TESTS ON TRANSVERSE RINGS

Location of Test	Nose Ring		Front Ring		Back Ring		Tail Ring	
	Lyon	N.T.	Lyon	N.T.	Lyon	N.T.	Lyon	N.T.
12:00	209	195	229	269	223	229	229	255
1:00		212		274		250		248
2:00		207		240		223		207
3:00	207	201	241	241	229	212	235	262
4:00		207		228		241		241
5:00		207		235		212		237
6:00	212	212	229	207	223	221	229	229
7:00		198		262		237		241
8:00		201		241		237		269
9:00	207	201	235	277	229	262	237	255
10:00		207		277		282		244
11:00		212		285		225		250

Note: The above hardnesses were taken on the transverse rings used for etch tests shown in Figures 15 to 22 inclusive.



Section from Nose Test Ring of
500 Lb. Cold Formed L.D. Bomb Prototype T12
Produced by Lyon, Inc.

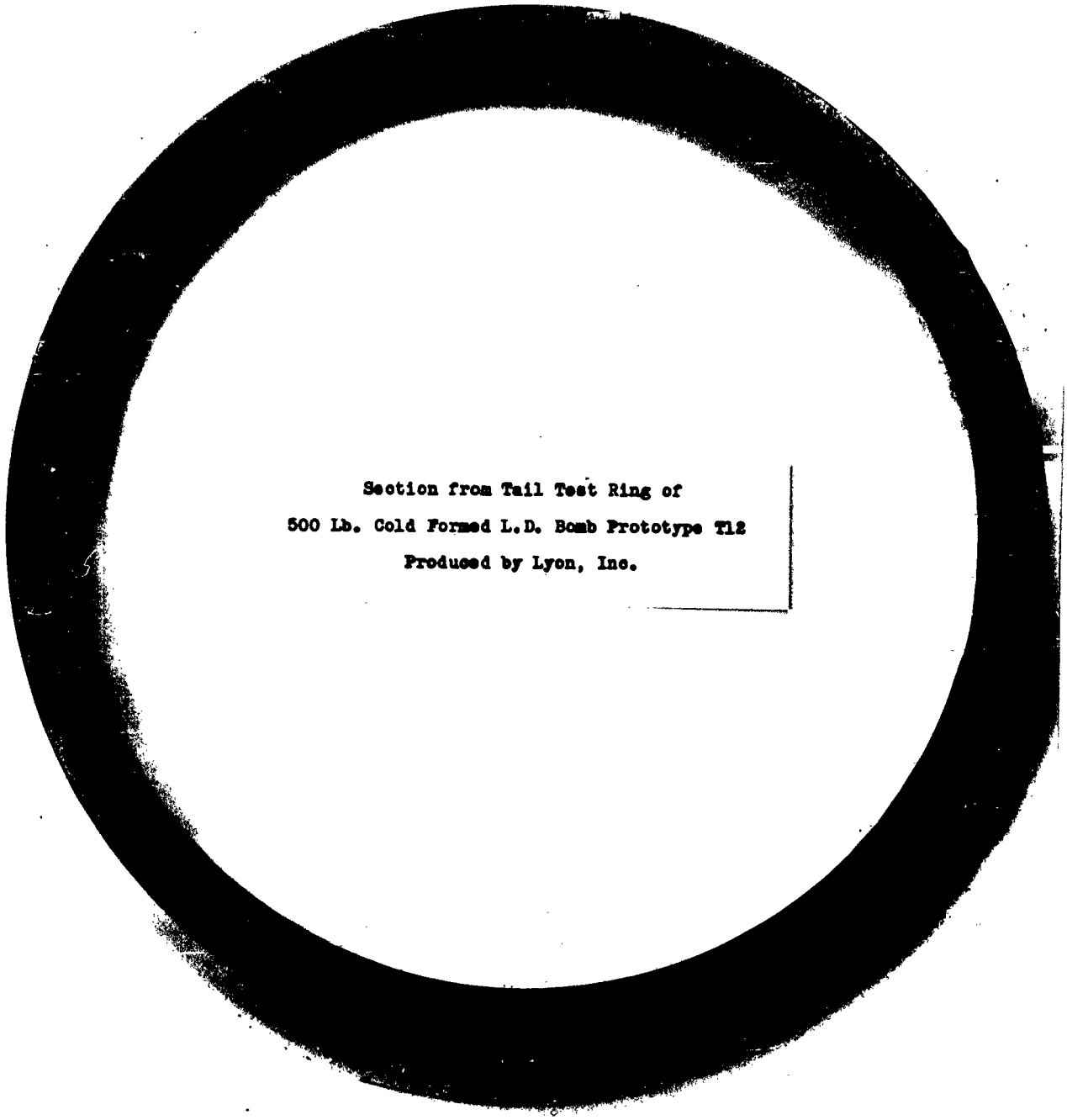
Figure 15

Section from Front Test Ring of
500 Lb. Cold Formed L.D. Bomb Prototype T12
Produced by Lyon, Inc.

Figure 16

Section from Back Test Ring of
500 Lb. Cold Formed L.D. Bomb Prototype T12
Produced by Lyon, Inc.

Figure 17

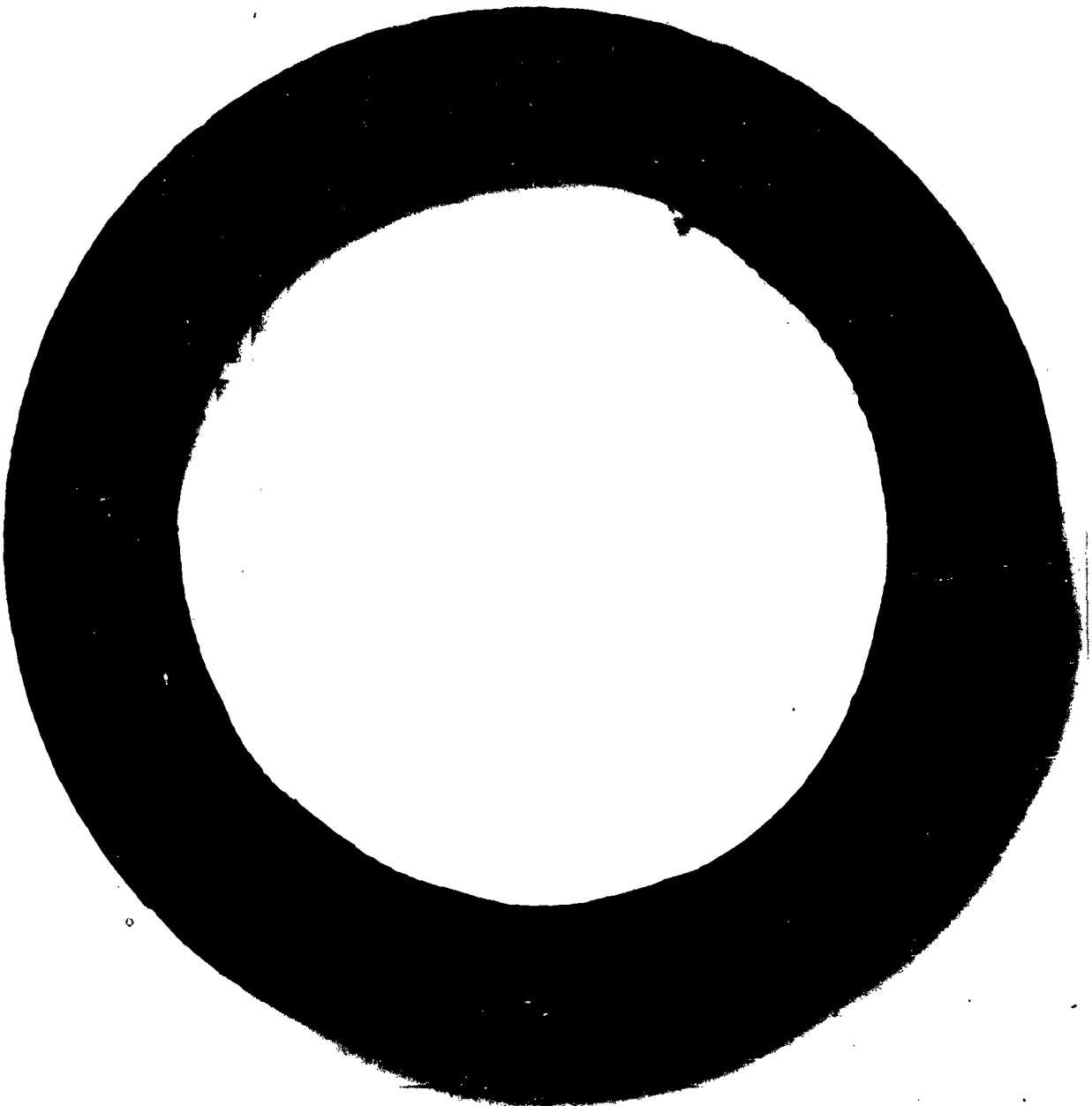


Section from Tail Test Ring of
500 Lb. Cold Formed L.D. Bomb Prototype T12
Produced by Lyon, Inc.

Figure 18

NP9-70171

CONFIDENTIAL

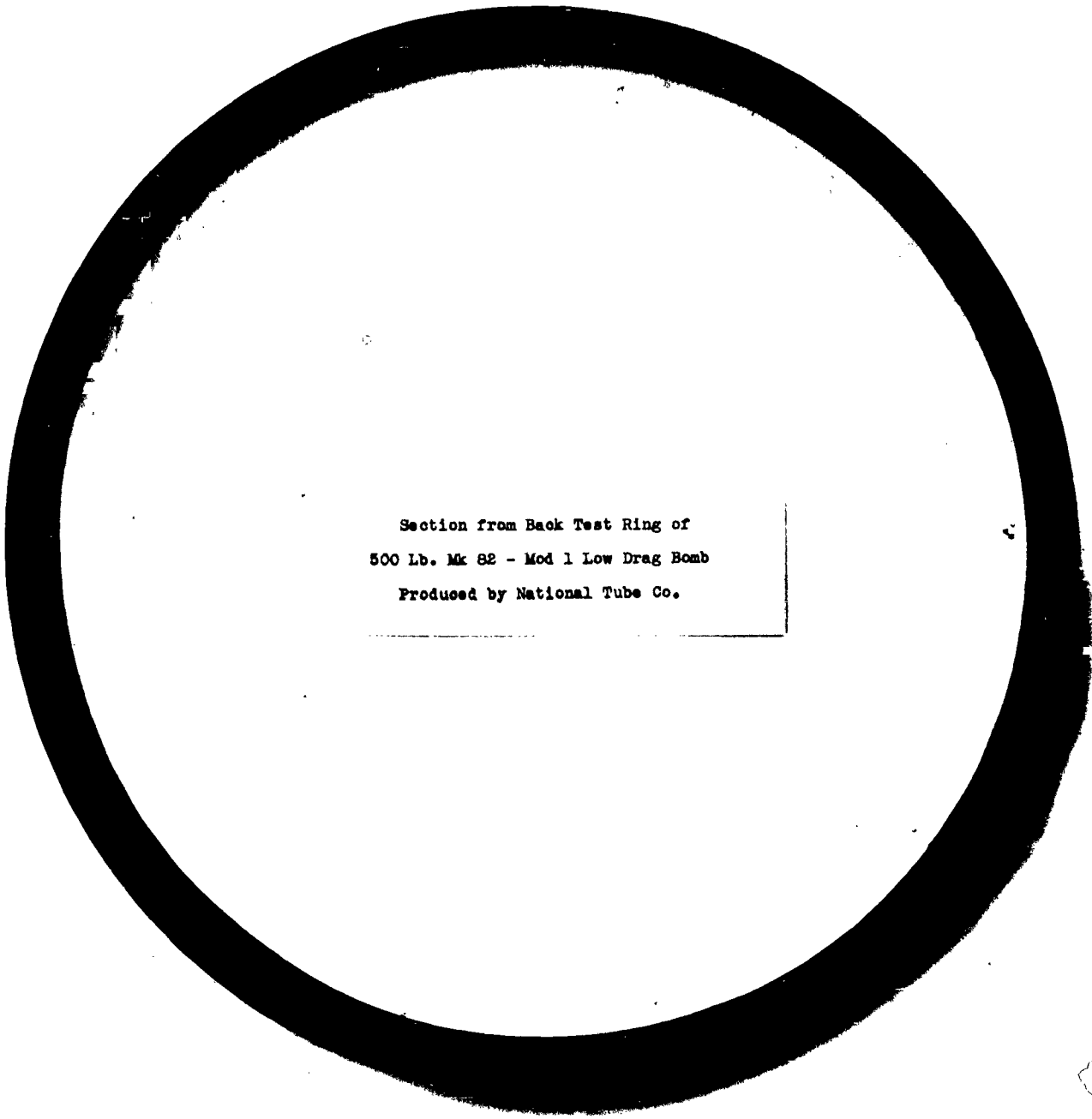


Section from Nose Test Ring of
500 Lb. Mk 82 - Mod 1 Low Drag Bomb
Produced by National Tube Co.

Figure 19

Section from Front Test Ring of
500 Lb. Mk 82 - Mod 1 Low Drag Bomb
Produced by National Tube Co.

Figure 20



Section from Back Test Ring of
500 Lb. Mk 82 - Mod 1 Low Drag Bomb
Produced by National Tube Co.

Figure 21

Section from Tail Test Ring of
500 Lb. Mk 82 - Mod 1 Low Drag Bomb
Produced by National Tube Co.

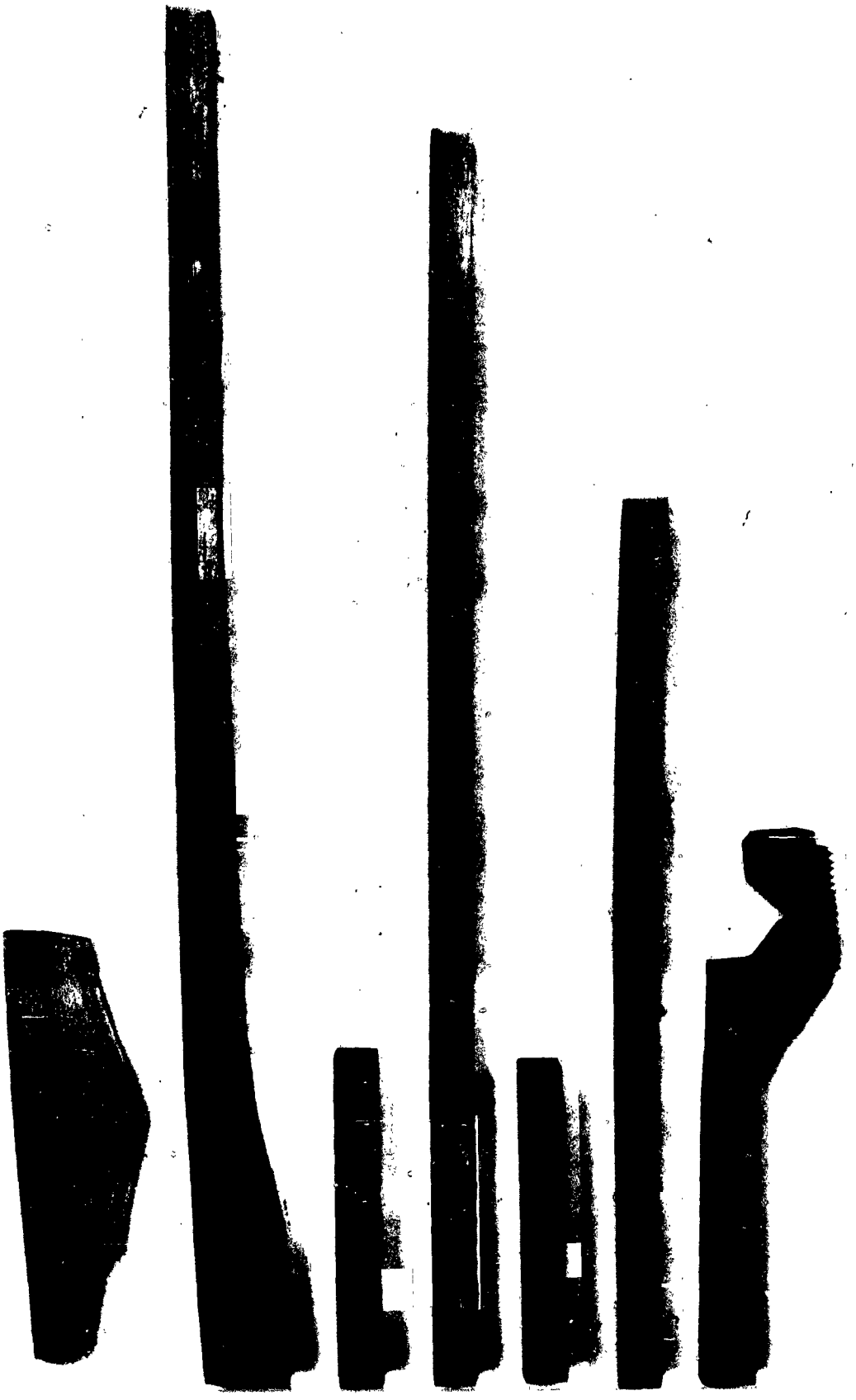
Figure 22

TABLE 12 BRINELL HARDNESS (3000 KG. LOAD)

Taken at 1" Intervals from Nose (#1)
to Base (#59) at 1:30 and 7:30 Locations

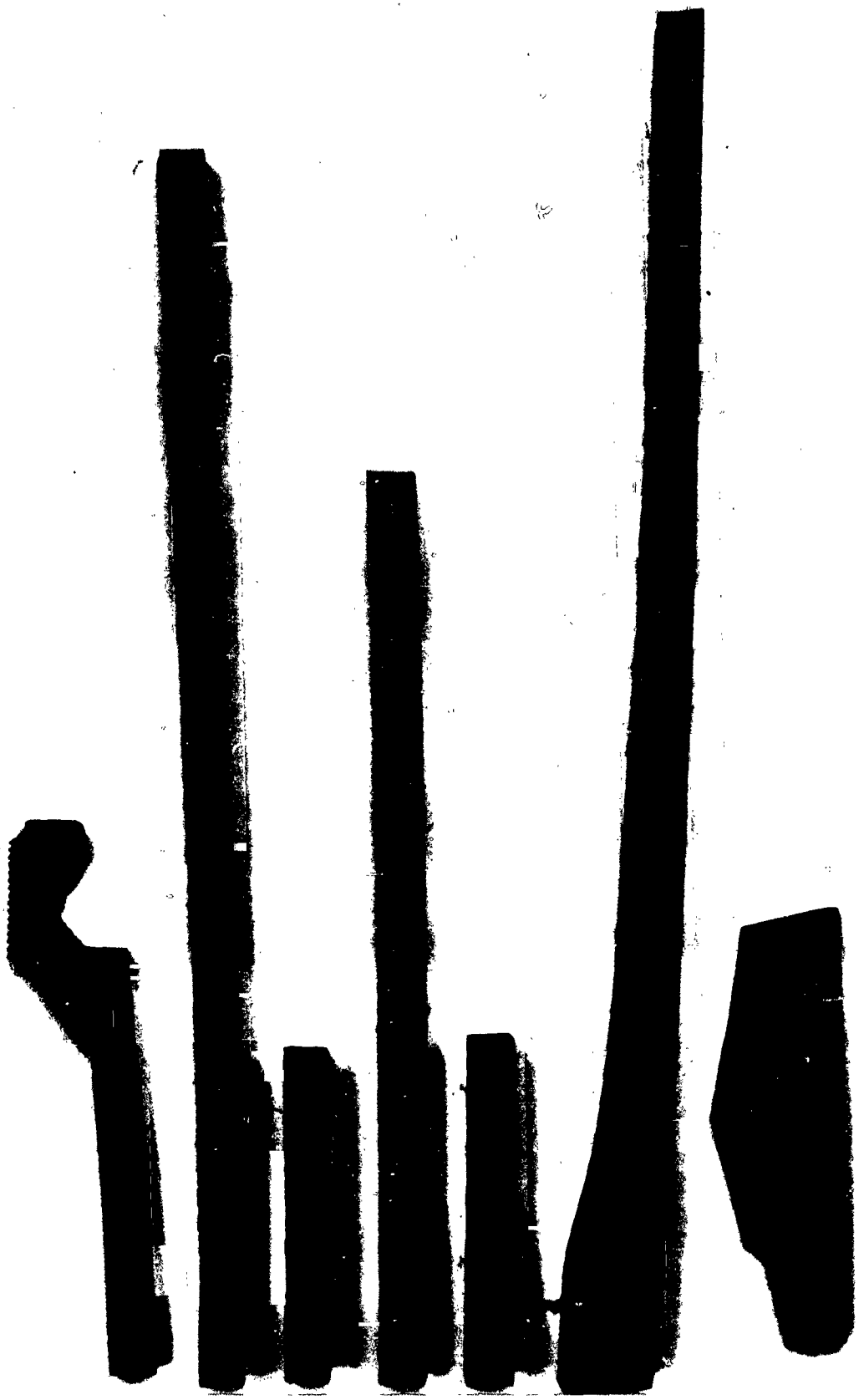
Test No.	Lyon Bomb 1:30	Lyon Bomb 7:30	N.T. Bomb 1:30	N.T. Bomb 7:30	Test No.	Lyon Bomb 1:30	Lyon Bomb 7:30	N.T. Bomb 1:30	N.T. Bomb 7:30
1	223	223	215	212	31	240	241	269	255
2	221	221	214	211	32	235	241	262	259
3	215	217	212	207	33	240	240	269	280
4	209	207	215	205	34	240	237	248	257
5	207	207	217	207	35	239	240	223	262
6	209	209	218	226	36	239	240	221	259
7	204	204	226	232	37	237	239	232	241
8	205	205	223	231	38	239	240	262	248
9	203	203	224	229	39	239	240	248	212
10	204	205	219	228	40	240	240	277	241
11	205	207	222	255	41	240	240	277	231
12	209	212	239	227	42	239	240	282	244
13	226	226	252	237	43	239	239	255	257
14	235	235	231	240	44	241	241	217	255
15	240	242	237	241	45	241	241	212	235
16	242	242	252	237	46	239	241	217	229
17	242	245	255	217	47	241	240	215	241
18	245	244	262	223	48	241	241	217	239
19	245	244	265	244	49	241	240	223	248
20	244	244	275	250	50	240	241	235	255
21	244	244	269	226	51	240	240	237	255
22	242	244	266	230	52	239	239	231	252
23	244	242	260	252	53	239	237	248	241
24	244	245	266	257	54	235	235	231	244
25	241	241	252	255	55	235	239	235	241
26	240	241	277	245	56	232	229	197	229
27	240	240	277	241	57	217	223	183	226
28	240	240	269	252	58	207	207	183	214
29	241	241	269	266	59	212	212	179	183
30	241	240	255	262					

Note: The above hardnesses were taken on the longitudinal strips used for the etch tests shown in Figures 23, 24, 25 and 26.



National Tube 500 Lb. Bomb Section at 1:30

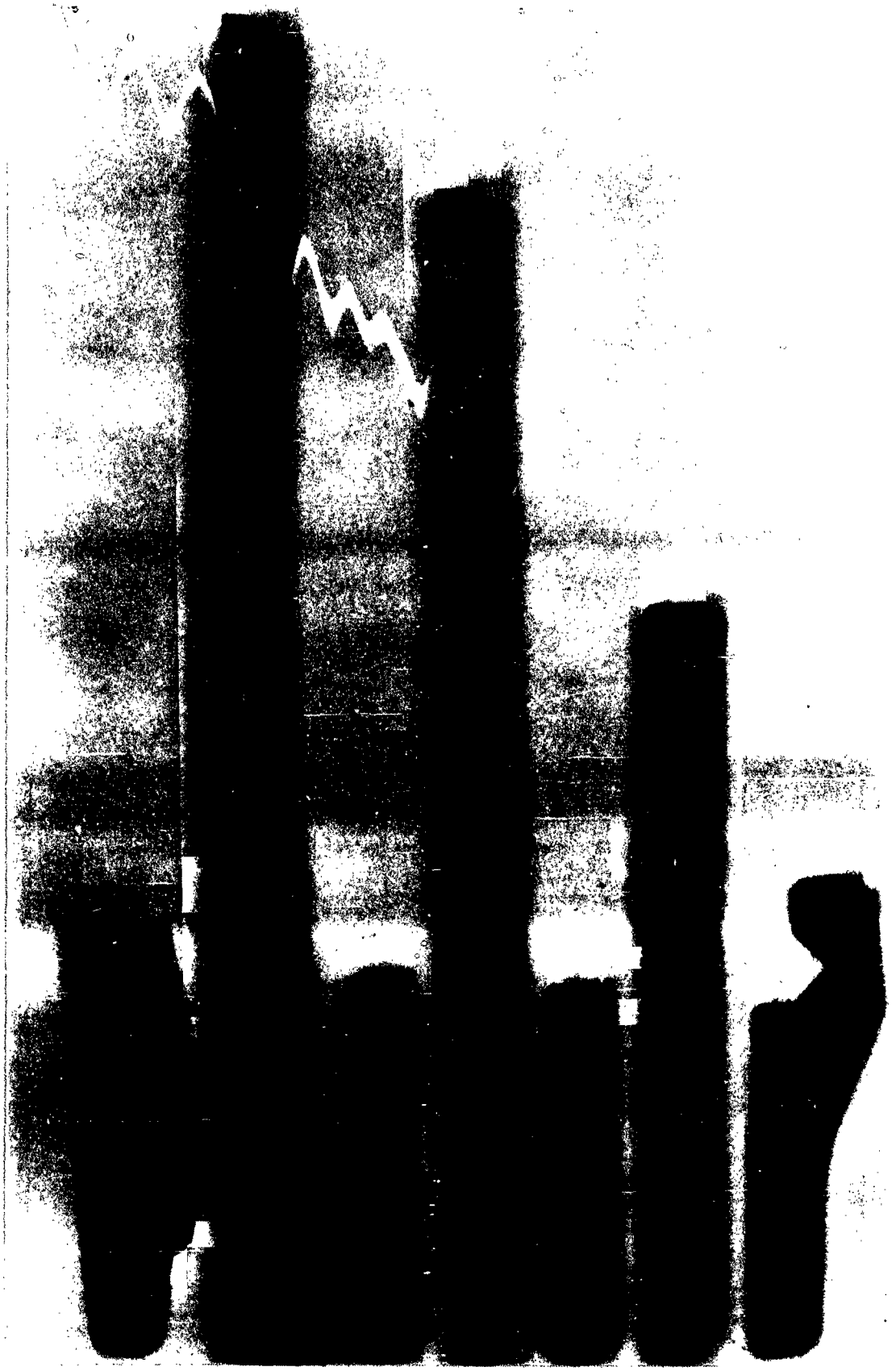
Figure 23



National Tube 500 Lb. Bomb Section at 7:30

Figure 24

Lyon, Inc. 500 Lb. Bomb Section at 1:30



Lyon, Inc. 500 Lb. Bomb Section at 7:30

Figure 27 Nose

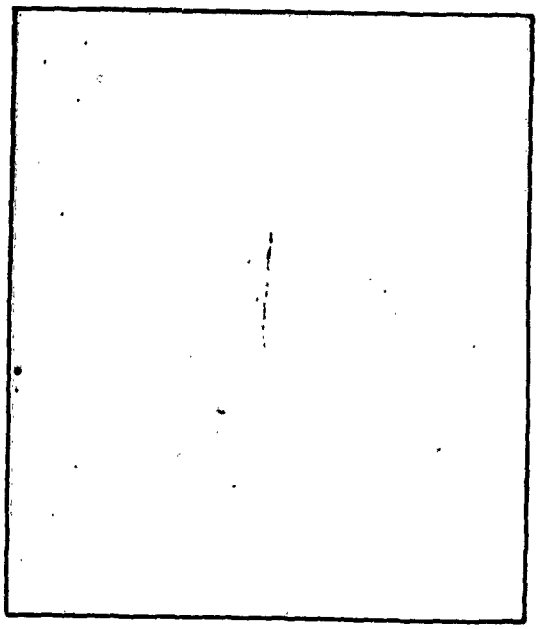


Figure 28 Front

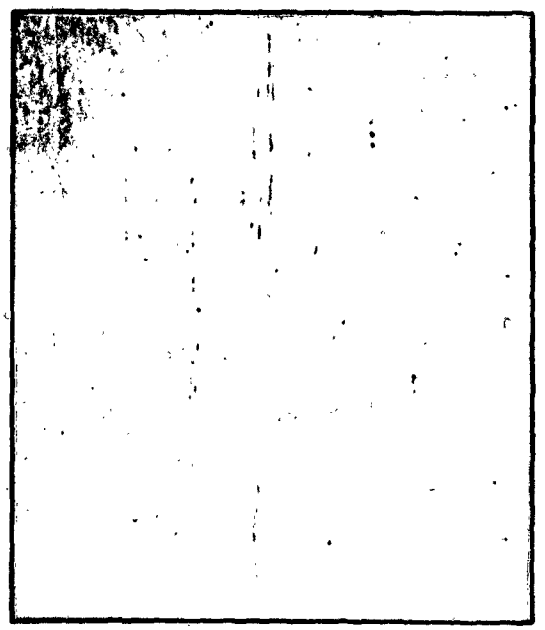


Figure 29 Back

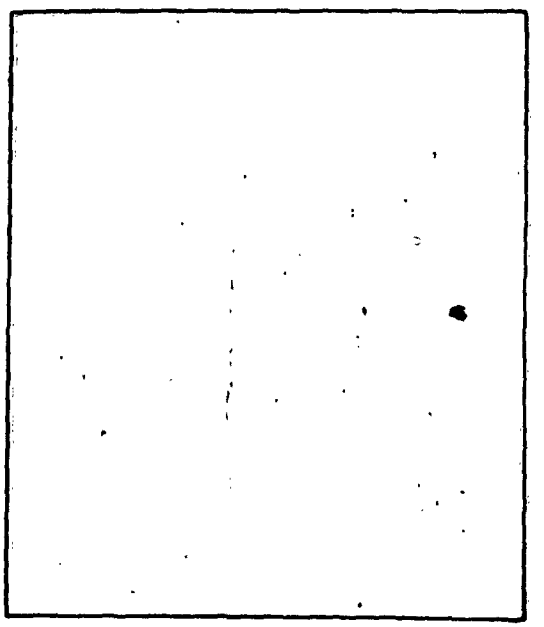


Figure 30 Base

NP9-70187 Lyon Cold Formed Bomb
CONFIDENTIAL Unetched Magnification: 100X

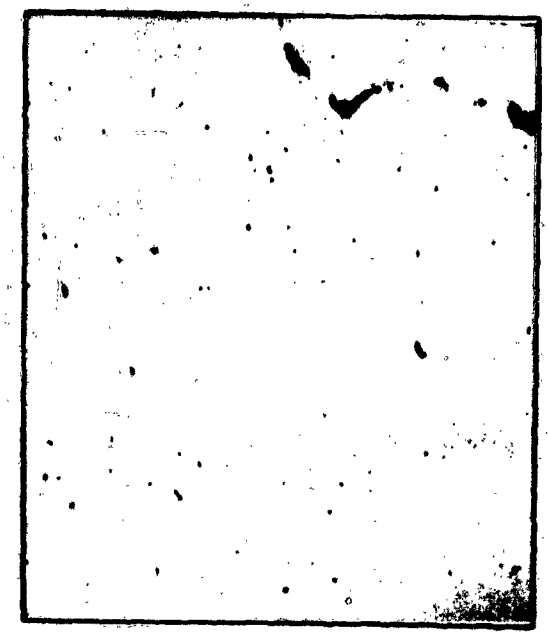


Figure 31 Nose

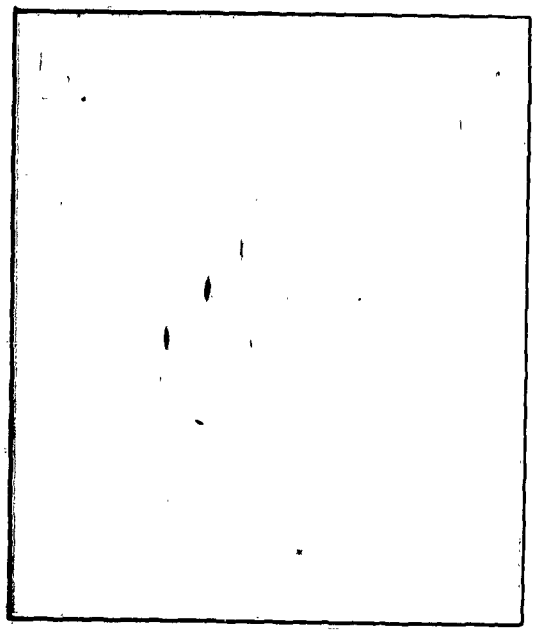


Figure 32 Front

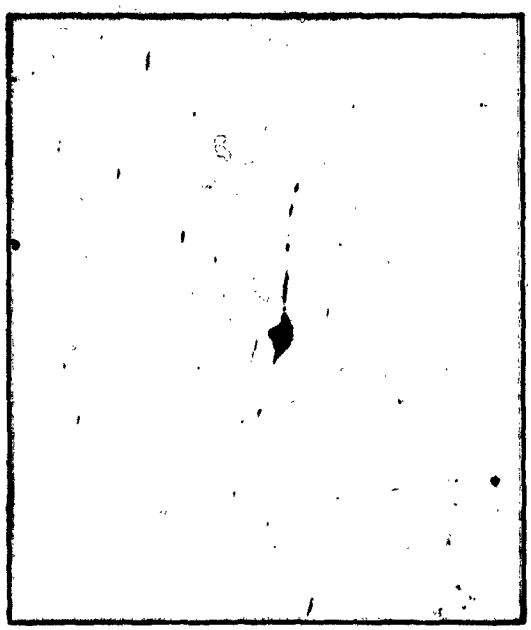


Figure 33 Back

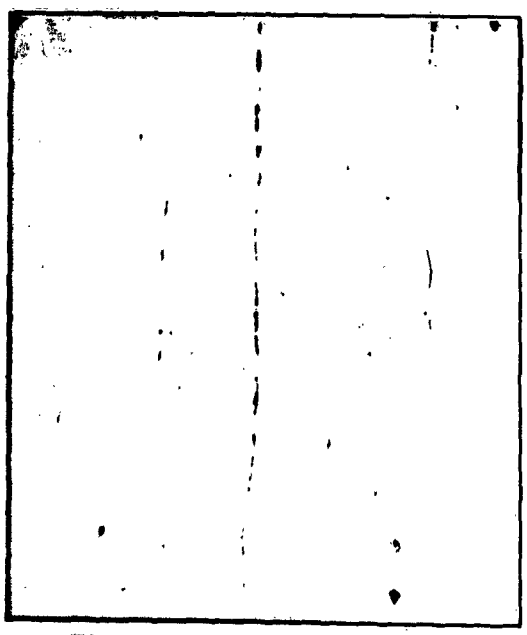


Figure 34 Base

MP9-70188 National Tube Forged Bomb
CONFIDENTIAL Unetched Magnification: 100X

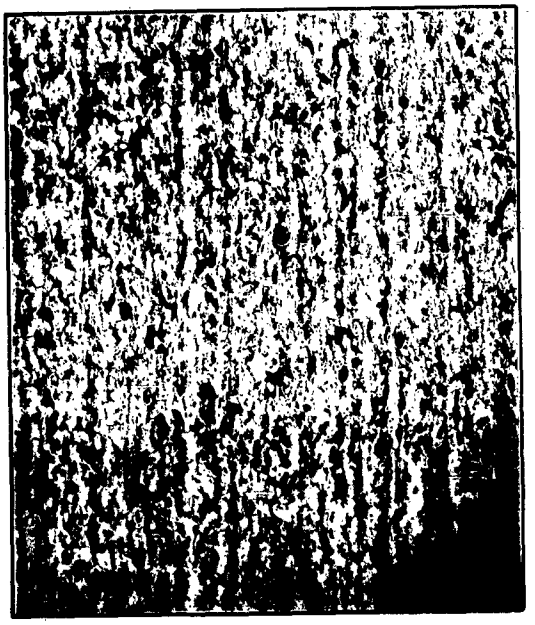


Figure 35 Nose

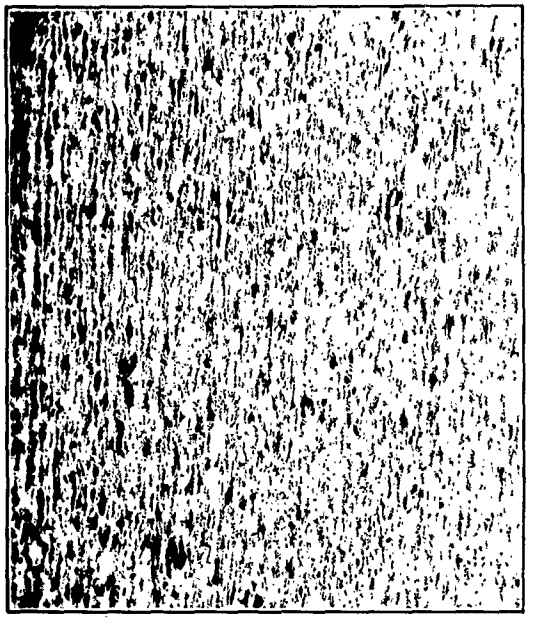


Figure 36 Front

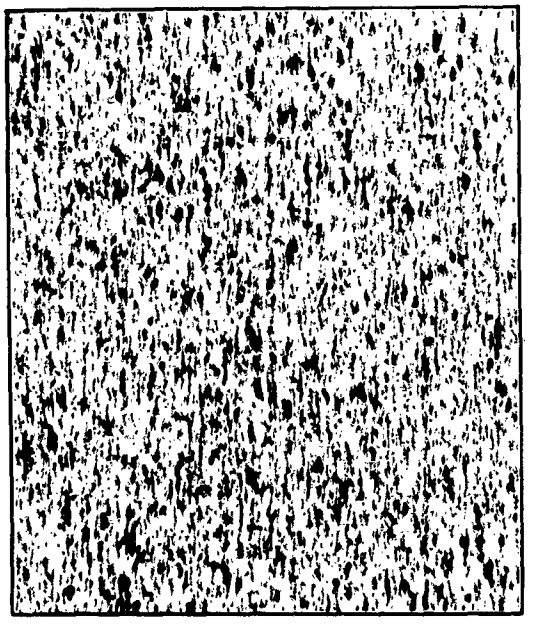


Figure 37 Back

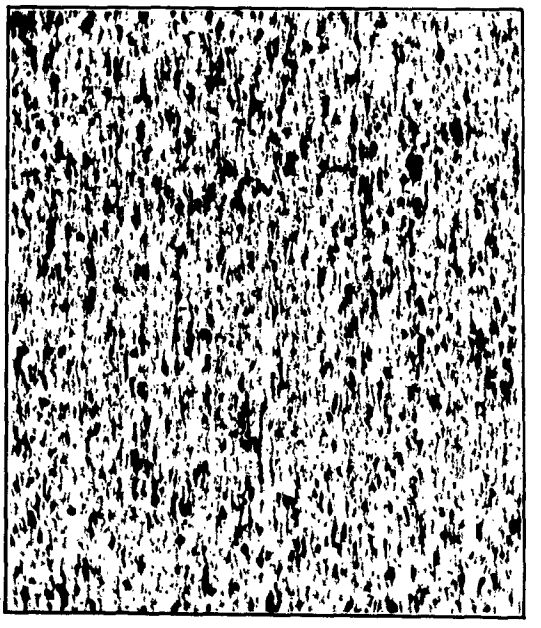


Figure 38 Base

NP9-70189 Lyon Cold Formed Bomb
CONFIDENTIAL Nital-Picral Etch Magnification: 100X

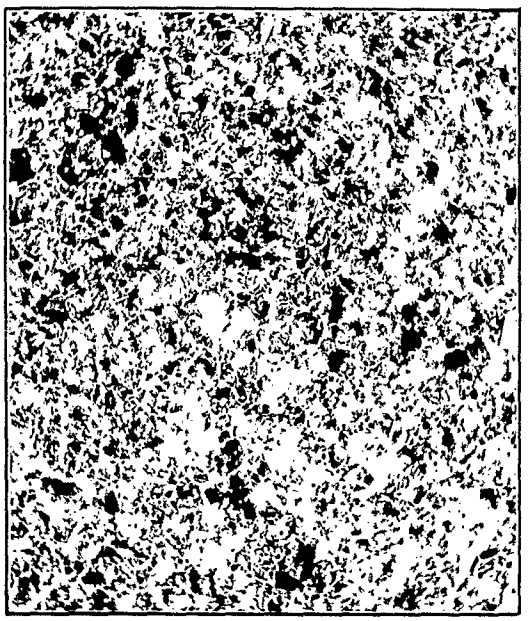


Figure 39 Nose

Figure 40 Front

Figure 41 Back

Figure 42 Base

NP9-70190 National Tube Forged Bomb
CONFIDENTIAL Nital-Picral Etch Magnification: 100X

Figure 43 Nose

Figure 44 Front

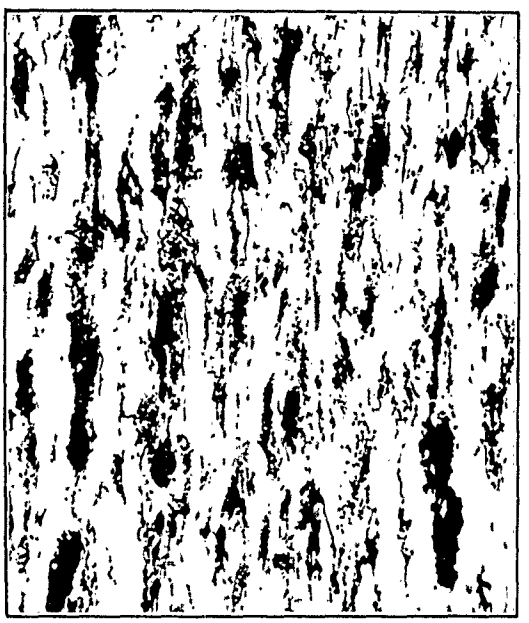


Figure 45 Back

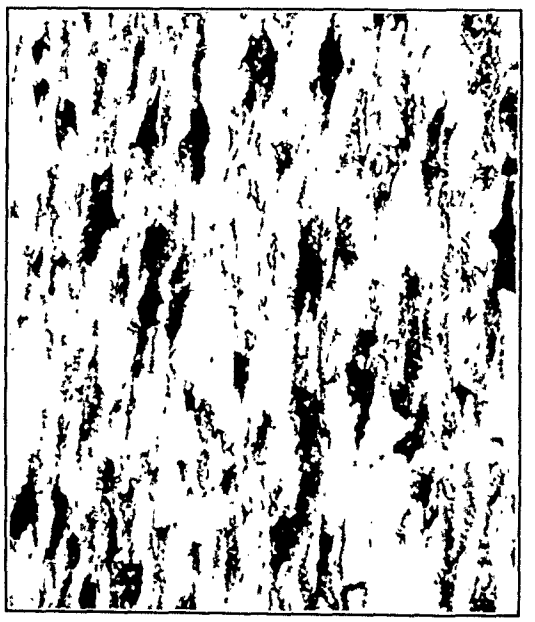


Figure 46 Base

NP9-70191 Lyon Cold Formed Bomb
CONFIDENTIAL Nital-Picral Etch Magnification: 500X

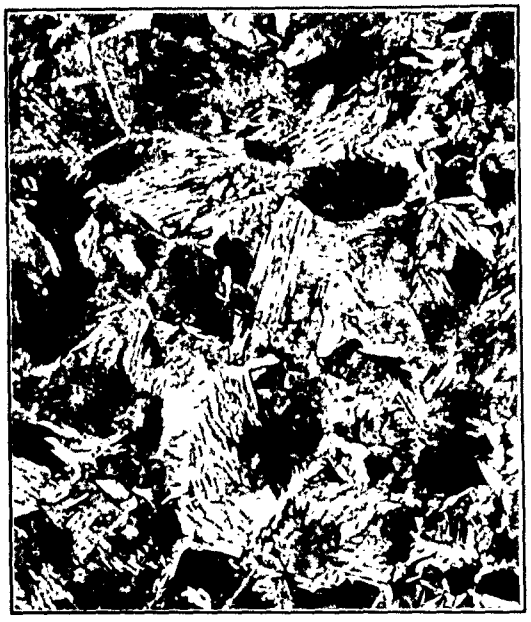


Figure 47 Nose

Figure 48 Front

Figure 49 Back

Figure 50 Base

NP9-70192 National Tube Forged Bomb
CONFIDENTIAL Nital-Picral Etch Magnification: 500X

APPENDIX F

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Naval Proving Ground. NPG Report No. 1452.
PLATE PENETRATION TESTS OF SPECIAL TEST MODEL 500 LB. LOW DRAG G. P. BOMB BODIES, by F. W. Kasdorf and W. H. Hall. 12 Apr 1956. 11 p. 50 figs. 12 tables. CONFIDENTIAL

Lyon Incorporated of Detroit, Michigan has developed under the sponsorship of the Bureau of Ordnance a method of cold forming 500 lb. Low Drag GP Bomb bodies from commercial steel plate. The purpose of this development is to determine if a suitable bomb body can be fabricated that will use non-strategic low carbon steel, eliminate as much welding as possible, and show a considerable cost saving over the currently manufactured bomb body.

Metallurgical tests in the NPG laboratories indicated that the failure of the Lyon bomb was caused by lack of ductility and toughness, particularly in the nose section of the bomb.

1. General purpose bombs - Penetration
2. General purpose bombs - Manufacture
3. Bombs - 500 lb. - Mark 82

I. Kasdorf, F. W.

II. NPG-W4-3c-321-1-56

CONFIDENTIAL

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2. General purpose bombs - Manufacture
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3. Bombs - 500 lb. - Mark 82

I. Kasdorf, F. W.

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I. Kasdorf, F. W.

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